AN STIONS
FOR TEACHERS

TO ACCOMPANY

"ELEMENTARY BIOLOGY"

GRUENBERG

MANUAL OF SUGGESTIONS FOR TEACHERS

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"ELEMENTARY BIOLOGY"

BY

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PREFACE

This manual is intended to aid the teacher in organizing instruction material and ideas for effective presentation in connection with the author's "Elementary Biology." It is no substitute either for a knowledge of the subject matter or for the technique of teaching.

Since the text which the manual is to accompany is largely concerned with showing how a knowledge of living things helps human beings, the notes here offered are largely concerned with suggesting interpretations and applications. The method of treatment implied throughout assumes a changing body of knowledge for the teacher, and a changing civic and intellectual environment for the pupil. New problems and new needs calling for additional knowledge, new discoveries enlarging the horizon, new thought bringing new insight and new significance — these represent the permanent stream, to be surveyed in its main ramifications even while it flows. This means imagining as well as remembering, it means doubting as well as believing, but it means also, of course, learning much more outside the book than in it.

The references are all useful; but even the most specific and authoritative are transients. Here the intention is to guide teacher and pupil to the use of the printed page with some judgment as to relative values. It is assumed that there will be available monographs and encyclopedias, manuals for the identification of various groups of plants and animals, textbooks, and current publications of all sorts.

The teacher should be constantly on the lookout for developments that suggest new problems and new applications in which biology is significant. Many lines of publication are currently available for the mere asking; others have to be ordered as they

appear. There should be in every high-school or college library the monthly circular of new publications issued by the United States Department of Agriculture; the one from the Public Health Service; and the one from the Bureau of Education. The local and state departments of health and of agriculture, the nearest Experiment Station, the Bureau of Fisheries, and similar agencies may be drawn upon for helpful and pertinent material. And every teacher should keep within hailing distance of what appears in the technical journals.

B. C. G.

MANUAL FOR TEACHERS

PART I. THE WORLD IN WHICH WE LIVE

I. INTRODUCTION

Ask pupils to report such examples as they may happen to have of *applied biology*; that is, of practical use being made of knowledge or understanding about living things. The history of civilization is a continuous record of the displacement of superstition by insight. Get examples of superstitions that have to do with health and disease; with the phases of the moon in relation to crop production; with lucky and unlucky signs in relation to fishing and hunting or the performance of other practical tasks. Why do we call these beliefs superstitions, and how do we distinguish them from our own true beliefs?

Have a committee of two or three students prepare a composite list of all the examples that have been submitted, with some classification of the material.

Have students bring together what they can of the usages of former generations with relation to epidemics and other diseases; with relation to insuring good crops, etc. Compare the average length of life and the death rates at various periods and in different countries. Compare yields per acre of various crops at different periods and in different countries. How have these changes come about? How have they *been brought about*?

References. LOCY, W. A., Biology and its Makers, pp. 1–8. WHITE, ANDREW D., Warfare of Science and Theology, chap. i. Yearbooks of the United States Department of Agriculture. Annual Reports of the State Department of Health; City Board of Health; Surgeon General, United States Public Health Service; Surgeon General, United States Army. "National Vitality," *Bulletin No. 30* of the Committee of One Hundred on National Health, Government Printing Office. Work of Vesalius. Life and work of William Harvey.

II. WHAT GOES ON IN THE WORLD

The purpose of these lessons is to acquaint the pupils with some of the common physical and chemical processes. Some of these are directly concerned in vital processes; others are helpful toward an understanding of more complex relations. Incidentally, we may lay the foundations of whatever thinking our pupils are capable of attaining by introducing the first laws of matter and motion, and the idea of *evolution* in the broad sense of continuity and causality. Where students have already studied elementary science this part may be omitted, or perhaps reviewed briefly.

The laboratory work should be in the nature of demonstrations, rather than experiments in the strict sense. The first few lessons might well be carried out with the text in the hands of the pupils, and the exercises completed, or at any rate started, in the class.

Things change. After reading section 7, have the pupils divide a sheet of paper into four columns, headed as below:

WEATHER	PLANTS	HUMAN BEINGS AND OTHER ANIMALS	NON-LIVING OBJECTS

In *each* column are to be listed as many kinds of changes as the pupils can think of that happen to the kinds of things suggested by the heading of the column.

Physical changes. Section 8 may be illustrated by melting a lump of ice in a pan, through applying the flame of an alcohol or Bunsen lamp. After calling attention to the change, the heat is again applied until the water is all gone. Melt a piece of paraffin or a bit of candle and continue to heat, without, however, starting decomposition or igniting.

Make three lists of substances with which you are acquainted. In the first list place the names of those that may exist in all three states; in the second, those that exist in only two states; and in the third, those that exist in only one state.

Note that the metal mercury is liquid at ordinary temperatures, and that practically all metals may be volatilized at high temperatures.

Demonstrate *solution* by placing sugar, salt, marble, starch, etc. in tumblers of water.

Chemical changes. Prepare three large test tubes or tumblers, a solution of washing soda (about four tablespoons to the pint), a solution of barium chloride, a solution of phenolphthalein, and some dilute hydrochloric acid. Before the class call attention to the similarity in appearance of the four solutions. That they are not really the same kind of stuff is to be demonstrated. Place the soda solution in the three test tubes; in succession add portions of the three other solutions. You will obtain a precipitate, a change in color, and an effervescence. The three distinct reactions indicate the occurrence of *chemical changes*.

Have the pupils describe these examples of chemical change, not in terms of the materials used and the materials produced, but in terms of the phenomena observed. Two apparently similar liquids produce, when mixed, a solid, insoluble substance and a new liquid, — one that can be shown to have properties different from those of either of the two used in the first place. Two others produce some gas, and so on. It is possible in each case to show that some distinct kind of substance has disappeared and that some new kind of substance has been formed.

Demonstrate the reversibility of the chemical changes manifested when a solution containing litmus or phenolphthalein is alternately changed from acid to alkali and the reverse. Use dilute HCl and dilute $NaOH$ solution. Have students suggest all the examples of color changes with which they are familiar; some of these will be chemical changes.

Have students give examples of chemical changes that have not yet been brought to the attention of the class. Make as complete a list as possible of physical changes and one of chemical changes.

Get a committee of students to compile the lists of the whole class, indicating the number of times each particular kind of change is mentioned and bringing in for class discussion and conclusion all doubtful cases.

Complexity of matter. Use magnifying glasses and bits of granite, gneiss, marble, and other minerals to get the idea of *heterogeneity*, — not necessarily the word.

Milk may be analyzed, to show that it is made up of several distinct parts. The specimen of milk is allowed to stand overnight in a four-ounce wide-mouthed bottle, covered against dust.

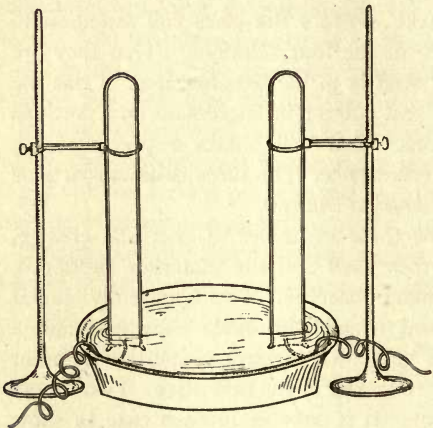

FIG. 1

The cream, or *fat*, separates out. In regions that are acquainted with dairy processes, the time may be shortened by the use of a centrifuge, or separator. If the milk has not soured, and there is nothing to be gained by delaying the demonstration, the milk may be immediately curdled by the addition of a few drops of acetic or some diluted mineral acid. (The casein is held in solution by the natural alkalinity of the milk, and is precipitated on neutralizing or acidifying.) Separate the *curd* and the *whey* by filtering through paper. The whey may be further analyzed by evaporating over a flame, in a porcelain dish. This shows the whey to be made up of *water* and *solid*. The solid residue may now be further broken up by ignition, showing that it is made up of a part that can burn and a part that cannot burn, — the *ash*.

Have pupils make a list of the fractions of the milk that can be readily recognized as distinct, — as fat, curd, water, solids-in-whey-that-can-burn, ash.

Have ready for inspection specimens of alcohol, ether, benzine, gasoline, etc. as examples of liquids that appear to be homogeneous;

and rock candy, a lump of glass, and a clear crystal of quartz or alum as examples of solids that appear to be homogeneous.

Wherever it can be managed, it is worth while to demonstrate electrolysis of water, with a test of each of the two gases produced. If a eudiometer is not available, set up two large test tubes, filled with the acidulated water, over the two poles of a direct-current system (see Fig. 1).

If you have a eudiometer, burn the hydrogen from a small glass jet and collect the vapor in a cold bell jar or battery jar held above the flame.

Elements and compounds. Have a collection of elements; these can usually be borrowed from the chemical laboratory. The pupils should see elementary sulfur, phosphorus, carbon, sodium or potassium, iodin, iron, magnesium, and silicon. It is not difficult to get specimens of platinum, gold, silver, nickel, aluminum, lead, tin, copper, and zinc.

Energy; energy and matter. Reëxamine the first list of changes prepared, or the list of physical and chemical changes; next to each item of change have students write the name of the kind of energy that brings the change about. Heat has already been shown to cause changes in state; it produces *motion*, as in the thermometer. This can be demonstrated on a large scale by gently heating a flask full of water closed by a pierced stopper carrying a glass tube (see Fig. 2). A little red or blue ink may be added to the water to make it visible in all parts of the room. Magnetism may be demonstrated with an electromagnet or with a permanent magnet (bar or horseshoe). The other forms of energy mentioned, with the exception perhaps of the X rays, have either been studied before or may now be demonstrated, so far as needed.

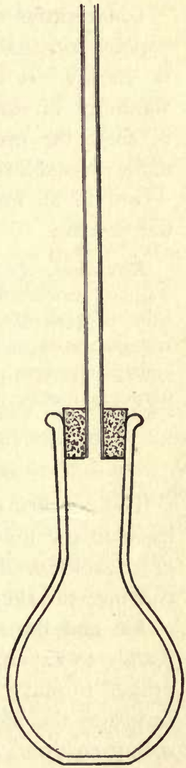

FIG. 2

Students should get the idea that all events are connected in series, and this study may well end by having them describe, in writing, one or two chains of happenings, in which the change in energy as well as the change in matter is indicated for each link.

Conservation of energy. Many children come to school with the superstition that machines are devices for increasing the amount of energy. It is well to clear up any misgivings or misunderstandings on this point. Machines vary as to efficiency, — that is, as to the proportion of all the energy they receive that they make available in the special work for which they are intended, — but in all machines the output of energy is exactly equal to the income.

References. PEARSON, KARL, Grammar of Science, chap. i. Have students report on readings in any accessible textbooks in physics, chemistry, or general science on such topics as physical changes, chemical changes, work, states of matter, conservation of matter, conservation of energy, elements, compounds, forms of energy, transformation of energy, perpetual motion, the philosophers' stone, efficiency, etc.

III. FIRE

The concern of the student of life with fire is sufficiently indicated in the text. The experiment suggested in section 17 is not practicable for the ordinary laboratory, and would not in any case convince the skeptic.

Air and fire. Here we meet problems that lend themselves readily to experimental treatment, and the opportunity should be utilized to make clear *the method of the experiment.* A candle flame furnishes the most convenient "fire" for these experiments, and a Bunsen or an alcohol flame, or both, will be convenient to have at hand.

The *flicker* of the flame suggests that burning liberates motion in addition to light and heat, but it may well be that this motion is imposed upon the flame by air currents, as is the case with the trembling of leaves, for example, or the movement of the shirt on the clothesline. Here we may find out *by trying*, that is, by experiment. Emphasize the important fact that we have here a

problem the solution of which we shall seek not in authorities, or in the records of other people's beliefs and opinions, but in the materials and forces at hand. Have the problem formulated clearly by the pupils, that there may be no ambiguity as to just *what* we are trying to find out. *How*, then, shall we find out? A second item involves the use of various materials. Record should be made of the *things used*. Then what is *to be done* with the things? The generalized scheme for the experiment is, *to shut off air currents*. Many suggestions may be made by the pupils, and the suggestions will in turn be criticized. There should be substantial agreement on the most reasonable or the most convenient method to be pursued or material to be used. A lamp chimney [1] has the advantage that it may surround the flame on all sides, and that it is transparent. Produce the lamp chimney and set it over the burning candle. The flickering stops, and this *result* may be sufficient to satisfy the pupils with the *conclusion* that the flicker is due to outside disturbances. If there is any disposition to discuss the matter further, be careful to remove the chimney before the flame is extinguished; it may be put on and taken off several times before the question is closed. As the discussion nears its end, leave the chimney over the candle, and the flame will expire. This will at once suggest new issues, and many of the pupils will be prepared to explain that it is the exclusion of the air that resulted in the dying out of the flame. But before that can be taken up, make

[1] In general it is well to have the materials to be used in the day's work readily accessible in the laboratory or recitation room, but *not laid out*. When you — that is, the teacher *and* the pupils — decide that a lamp chimney would be desirable, the teacher's resources must be equal to the occasion. But no matter how carefully the teacher has prepared the day's demonstration, the procedure should never give the impression of being "cut and dried" in advance. Exception should be made for demonstrations that involve rather elaborate arrangements, or that take more time for setting up than the usual session allows. In that case, however, there is either no pretense that the experiment is performed in response to a problem that has arisen in the class, or, if you have led up to the problem, the *plans* for the experiment may be agreed upon at one session, with the understanding that the preparations will be made in anticipation of a future meeting of the class.

a complete record of the first experiment, insisting upon the logical sequence and clear analysis rather than upon the mechanical form of the record. These points should stand out clearly, whatever designations may be used:

1. *The problem:* the question to be solved.
2. *Materials and apparatus:* what was used.
3. *Operations performed:* what was done.
4. *Results:* what happened, what phenomena were observed.
5. *Conclusion(s):* the answer to the *question*, so far as it may be inferred from the *results*.

In insisting upon a correct record of the first experiment, we must shift the emphasis from the performance, as an interesting "stunt," to the *argument* involved in formulating the problem, in selecting materials and operations, in selecting the significant elements from the results, and in drawing conclusions.

When we have established this routine of *thinking* about experiments, less time will be required in the matter of form of records etc.

The second experiment, suggested by the expiration of the flame, centers on the question whether the flame *uses up* something in the air or *gives off* something that interferes with burning. The air being invisible, we must have some means of showing the increase or decrease in the volume of air. It may be that after several suggestions from the pupils, it will devolve upon the teacher to find a feasible plan. A cylinder large enough to go over the candle, and closed at one end, inserted over the lighted candle standing in a dish of water, will meet all the conditions. If the flame gives off gas(es), bubbles should be forced through the water, out of the cylinder; but if the flame uses up part of the air, what would happen? The possible results should be anticipated as part of the argument, before the operation is actually performed, but with the apparatus in hand.

Some of the pupils will probably jump to the conclusion that the flame uses up part of the air. But we must not be too sure. It is quite conceivable that both processes are going on at the

same time, but at different rates. Here is a problem for the chemist — to identify the gases concerned.

When the cylinder is finally placed over the lighted candle, the flame begins to fade, it flickers a few times, and finally expires. In the meantime the level of the water inside the cylinder changes in a way that indicates a reduction in the amount of gas included. We may also observe the condensation of moisture on the inside of the cylinder, and the ascent of the thin column of smoke from the wick. Which are the phenomena that are significant in relation to our problem? Obviously, the change in level of the water. What does that show? Probably that something in the air has been removed by the action of the flame. By means of a ruler held alongside the cylinder it may be possible to get an approximate idea of what proportion of the air has been thus used up.

But let us not overlook the possibility that something may be present in the jar (the air) that was not there before. We shall have to come back to the question whether the flame gave off something. There is the smoke, for example; and perhaps there are some *invisible* fire products. We may need the assistance of the chemist to answer the question. At this time we may be certain only that *something has been taken from the air by the burning.*

Now as to the chemical nature of the remaining gas (or mixture of gases), we should need some knowledge of chemistry to proceed farther. It is futile to test this air further with relation to fire, as some of the students are almost sure to suggest; for the failure of a flame to burn in this residual air cannot tell us anything that we did not already know. The teacher, drawing upon his fuller experience, produces a *reagent*, a substance that reacts distinctively with the various gases — in this case limewater. Yes, it is the same kind of limewater as is sometimes used in the baby's milk bottle. It is prepared by shaking up some calcium oxid (unslaked lime) with water, and filtering through paper. This should be kept in tightly stoppered bottles (cork is better than glass; but if glass-stoppered bottles are used, smear a little vaseline on the stopper, to make sure of an air-tight joint that will not become caked). A little limewater is placed in the

bottom of a cylinder similar to the one used in the experiment. Place a glass plate or the palm of the hand over the open end of the cylinder and shake up vigorously. The limewater does not change its appearance perceptibly. A little limewater is placed in the cylinder in which the flame had expired, the cylinder being quickly turned up and then quickly covered. When the limewater is shaken up, it turns cloudy or milky. This shows us at least that the two masses of air are *different*, although it does not tell us just what the difference is. We may therefore conclude that the burning process not only removes something from the air but also sets free something that was not there before.

The question may here be raised as to the relation between the products of combustion to the fuel, on the one hand, and to the materials removed from the air, on the other.

Burning a synthesis. It is a reasonable hypothesis that the product, like the visible ash of some other fires, is either some portion of the fuel thus set free, or a portion of the fuel or of the air modified in some way, or a *new combination* of materials, containing elements from the fuel, from the air, or from both.

The technique of testing these variations of the hypothesis is rather too complex for the schoolroom. We can, however, test the supposition that the product of a burning contains fuel substance plus air substance. For this purpose we must have a fuel the burning of which gives us a product that is easily gathered and weighed. We use magnesium ribbon, — magnesium because the product of its combustion is solid, and ribbon because it is convenient to handle.

A trip balance has a large funnel, closed with cotton wool in the stem, on one platform, with a strip of ribbon about eight inches long. This is counterbalanced until the platforms are level. A wire loop or hook may be hung into the funnel before adjusting the balance. The magnesium ribbon is hung from the loop and ignited with an alcohol or Bunsen flame, and the funnel is immediately replaced upon the platform of the scale. If the operation has been carefully conducted, the accumulated smoke or ashes will be found to *weigh more* than the original ribbon of magnesium.

Since the addition to the solid matter on the scale platform could have come only *from the air*, we are tempted to conclude that the air stuff that takes part in burning combines with something in the fuel.

The gases in the air. The three principal gases of the atmosphere may be prepared for laboratory use as follows:

Carbon dioxid. A wide-mouthed bottle or flask is fitted with a two-holed stopper. Into one hole is fitted a glass "thistle" tube reaching nearly to the bottom of the bottle. Into the other hole is fitted a bent glass tube reaching only a fraction of an inch below the cork or rubber and having a rubber tube attached to the outside arm (Fig. 3). This apparatus, or gas generator, may be used for generating hydrogen and for other purposes. To make carbon dioxid, place some marble chips (calcium carbonate) or limestone bits in the bottom of the bottle; insert the stopper with the tubes and pour water through the thistle tube until the chips are covered. Pour dilute hydrochloric acid (commercial will do) slowly into the thistle tube until effervescence begins. Place the free end of the rubber delivery tube in a pneumatic trough or in a dish of water. The bubbles coming through the water indicate the rate at which gas is being liberated. Carbon dioxid can be collected either with the help of a pneumatic trough or with a large dish of water, the tubes or bottles to be filled being held in the hand over the delivery-tube opening, after being filled and inverted. Be careful not to raise the mouths of the vessels out of the water while the gas is being collected. Four-ounce wide-mouthed bottles are

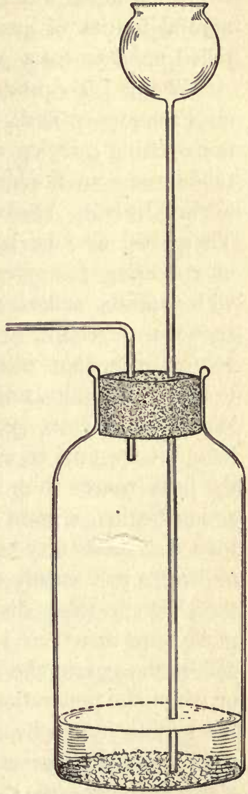

FIG. 3

convenient for these experiments. Glass squares smeared with vaseline may be used as covers for these containers; and if there is not too much water left in the bottles after the gas is collected, several bottles of gas may be prepared in advance and may be relied upon to react properly when wanted.

Nitrogen. To produce this gas there are needed a Florence or an Erlenmeyer flask, 250 cc. or 500 cc.; a rubber stopper with one opening carrying a short glass tube with a long rubber delivery tube; some ammonium chloride (sal ammoniac) and some sodium nitrite, $NaNO_2$. (Be careful not to use sodium nitrate, $NaNO_3$.) There will also be needed a pneumatic trough or other means of collecting gas over water, bottles with glass covers smeared with vaseline, and an alcohol or Bunsen flame. Place about a teaspoonful (level full or less) of sal ammoniac and about an equal volume of sodium nitrite in the flask; pour in just enough water to cover the salts, and insert stopper carrying the delivery tube. Warm the mixture gently over the flame, holding the flask in the hand all the time so as to be able to regulate the heat by moving the flask nearer to or farther from the flame. When the chemical action begins, a great deal of heat is generated within the flask; then it is necessary to apply only enough heat from the outside to keep up a steady action. After some gas has escaped from the delivery tube, displace the water in one or two bottles to make sure that there is no more air in the generating flask. Then collect the gas in the usual way. At the conclusion of the work, or when the generation of gas is stopped for any reason, be careful to take the delivery tube out of the pneumatic trough. The teacher should try out the making of nitrogen before attempting it in the classroom.

Oxygen. This gas can be produced by hydrolysis, if there is available a direct current of electricity, or by chemical methods. For small quantities, the decomposition of red oxid of mercury in a small tube by the application of heat is convenient. For making larger quantities to be used in experiments, the decomposition of potassium chlorate is the best method. A mixture of about equal parts of potassium (or sodium) chlorate and manganese dioxid

(both powdered) is placed in a large test tube or in a copper or iron still. If a test tube is used, close the end with a rubber stopper carrying a delivery tube; if a still is used, connect the outlet with a rubber delivery tube. The mixture of chlorate and dioxid is heated steadily (the glass tube being rotated to prevent melting the glass at one point), and the evolved gas is collected in the usual way. Be careful to remove the delivery tube from the water when the heat is withdrawn.

To demonstrate the fact that there are three distinct substances here, notwithstanding their resemblance to each other and to the air, a bottle of each gas, labeled, is set out, and we proceed to test them in turn, in relation to burning. A lighted splinter (cigar lighters are convenient) is inserted into a bottle of air for a few moments and then taken out; it is inserted thus in turn in the bottle of nitrogen, where the flame is instantly extinguished. The splinter is relighted and placed in the carbon dioxid, with the same results. It is finally placed in the oxygen, where it instantly blazes up into a more intense flame. Take the splinter out and extinguish the flame by shaking it or by blowing it out. While a spark still remains on the stick it is again inserted into the bottle containing oxygen. The spark bursts into flame. There can be no doubt left in the minds of the pupils that it is the oxygen of the air that is the significant factor in burning. Recall the experiment in which the portion of the air removed by the fire was seen to be approximately one fifth, and compare this with the known (from authorities) proportion of oxygen.

Oxidation. Review all that has been learned about burning, and get the idea of the products of combustion being specific kinds of compounds. It is well to have at hand specimens of sulfur, charcoal, magnesium, etc., for demonstration of burning elements. Get the generalization about burning that will include the burning of *liquid fuels* (alcohol, oils, benzine, gasoline, etc.), as well as of *gaseous fuels* (illuminating gas, marsh gas, hydrogen, gasoline vapor, etc.) and of solids.

If there is time, it is interesting and instructive to demonstrate the burning of iron with a flame, and to compare the product

with the rust produced by weathering of iron or by rusting *under water.* Ordinary picture cord may be used, the strands being unwound and a single strand at a time being employed. Use a quart jar full of oxygen, and ignite by dipping the looped end of the wire into sulfur (flowers) and igniting the sulfur. Now dip this into the jar of oxygen, and the iron will ignite and burn with a visible flame.

References. In any available books on chemistry, general science, or the history of science, or in encyclopedias and other books of reference, have pupils find material for special reports on such topics as air, oxygen, fire, Priestley and oxygen, Scheele and oxygen, Lavoisier and oxygen, Cavendish and the synthesis of water, explosion of gases, internal-combustion engines, spontaneous combustion.

PART II. LIFE PROCESSES OF THE ORGANISM

IV. LIVING THINGS AND NON-LIVING THINGS

With the more direct approach to living things as the object of contemplation, and eventually of study, the students should have before them constantly as many different kinds of living things as may be conveniently kept in the workroom. This does not mean that we should convert our laboratories or recitation rooms into menageries; but it is not unreasonable to have on hand a number of growing plants, in pots or in window boxes, one or two aquaria (both fresh and salt water if possible), a vivarium containing frogs, lizards, newts, various insects according to season, slugs and other animals, and a hay infusion. In addition there should be exposed prepared specimens, under glass, of as many plants and animals as the available cabinets will hold without making the collection a jumble. These should be supplemented with pictures of interesting forms that cannot otherwise come within the common experience of the children. Where there is an abundance of material the teacher will from time to time change the aspect of the collection, adding to the interest through novelty, and shifting the attention as the need for emphasis may direct.

As a preliminary exercise have the pupils prepare two lists of the names of objects, one list comprising *living things*, the other, *non-living things*. It may be necessary to explain that a *thing*, or object, is not to be confused with a *material*. For example, the earth may be considered an object, like the sun or the moon or a baseball; but *earth* is the name we give to a kind of stuff, like iron or wood or leather. We often call an object by the name of its most important or distinctive or sole material, as when we call a branding tool *the iron*, or a washer *the leather*, or a document

the paper. The point of this exercise is twofold: (1) It should help to clear up confusion between objects and classes of objects, on the one hand, and unformed matter on the other. (2) It should bring clearly into consciousness the relative paucity of formed objects in nature, other than *organisms*, and the practically universal fact that *life* is related somehow to *formed* matter.

It is well to have on view as many types of crystals as can be conveniently exhibited.

Before the study of the text the pupils should be encouraged to analyze their concepts of living things by listing all the characteristics of organisms that they can think of. These lists may then be used as a basis of criticism and discussion.

In the discussion of differences or similarities between living and non-living, the pupils should be encouraged to formulate their concepts in good sentences; and they should be encouraged then to modify their generalizations by expanding their observations to types that do not appear to agree with these concepts. Reference to the plants (that do *not* walk about), to the worms (that have *no* stomachs or brains), to the organisms *without* blood, etc., are largely in the nature of challenges, and pains must be taken to avoid driving the pupils to desperation. But it is possible gradually to get them to see that life is not to be comprised in a word or in a single differential.

About a week before the class is ready to consider growth, arrange a demonstration of inorganic growth as follows:

In the bottom of a battery jar or large fruit jar place a layer of clean sand. On the sand place a number of crystals, as of copper sulfate, ferrous sulfate, chrome alum, zinc sulfate, etc. Pour slowly into the jar a mixture of sodium silicate (water glass) and water, about one part to ten. The prepared jar is to stand undisturbed where it may be observed without being moved.

Saturated solutions of sugar, alum, and other substances that crystallize readily may be prepared, and the growth of crystals watched. By suspending a thread (weighted) in such a solution, the crystallization may be started, and the growth of the mass about the string as an axis may be watched. Compare rock

candy. It may be feasible to have the children prepare such growths at home.

Compare the assimilation of foreign peoples, or of new pupils in a school.

If there is not common familiarity with photographic materials and processes, demonstrate the modification of blue-print paper or printing-out paper under the influence of light.

In the study of functions the idea can be made more clear by emphasizing the fact that we think of use chiefly in terms of *human* advantage, and then contrasting *function* with *use*. For this exercise, have each student prepare two sheets of paper (or pages of the notebook) by dividing the space into four columns, headed as below:

NAME OF ORGANISM	PART USED	HOW USED	FUNCTION

One sheet is to be used for plants, the other for animals. A few illustrations will appear in the course of the discussion; these may be used to start the lists, and each pupil may then be required to bring say ten or a dozen on each list. The most commonly used parts of the more familiar plants and animals will serve as the most striking means for emphasizing the contrast between *use* and *function*, — for example, the tongue of the cow, the tail of the ox, the root of the carrot, the bark of the hemlock, etc.

Be careful at this point, as always, to keep clear of the preconceived notions of *purpose*. It can easily be made plain to even the least mature pupils that the function of a given organ is by no means an indication of purpose on the part of the organism. You have but to ask, "For what purpose did you grow yourself a liver?" or "What was your purpose in building four chambers into your heart?" — and the child sees at once that he grew up without purpose on his own part; and this repudiation of purpose may be extended to other organisms. It remains then a question

of Nature's purpose or God's purpose, which imply assumptions that we do not need for our purpose, or which imply interpretations that are of no use to us. At any rate, purpose must not be allowed to interfere with the purposes of our study.

References. HUXLEY, T. H., On the Physical Basis of Life, in his "Methods and Results," Essay 3; JORDAN and KELLOGG, Evolution and Animal Life, chap. iii; LOCY, W. A., Biology and its Makers, chap. xii; LOEB, JACQUES, The Organism as a whole, chap. ii; MORGAN, T. H., Evolution and Adaptation, chap. i; WILSON, E. B., The Cell, pp. 17–30. The abler pupils can read the first two of the above; have all look up in available books on botany and zoölogy such topics as protoplasm and cell.

V. THE LIVING STUFF

In comparing plants and animals, have living specimens within sight and within reach. See suggestions under IV.

Hay infusions prepared for protozoa usually die out in a short time. To keep a supply on hand use this method: Prepare a culture medium by boiling hay in water, with a little corn meal, until the liquor is of a dark brown color. Leave a small amount of the hay in the liquor. This may be kept indefinitely in sealed bottles. For use, expose some hay infusion in a battery jar for a day or two, in order to inoculate with bacteria from the air. Cover with a glass plate and leave until a scum appears. Then add some water, mud, etc. from a pond or ditch. Several jars may be prepared, and inoculated with material from different sources. In a few days the protozoa will be sufficiently abundant; the supply should last for several months. It is well to inoculate a fresh hay infusion every three or four months, using some of the old culture for this purpose.

Leaves of Elodea, myriophyllum, or other delicate water plants, filaments of spirogyra or other algæ, epidermal cells of almost any kind of leaf, or onion skin, will give sufficient material for forming the idea of cells as structural units, as well as something of the nucleus, vacuoles, and non-living bodies within the cell. Animal cells are better shown from prepared slides. Call attention to the fact that the colors in such specimens are due to the artificial stains used for the purpose of making the structural details visible.

It may be worth while to give the pupils some instruction in the use of the microscope. To familiarize students with the inversion of the image, it has been found helpful to prepare a set of slides by mounting permanently in balsam tiny bits of paper cut from some printed matter (small type, one side of paper only), each containing two or three letters. These slides are studied with the naked eye, with the simple microscope, and with the low power of the compound microscope. The making of drawings of the object under these three conditions, with the slide always kept in the same position in front of the student, will accelerate the formation of the ideas needed in the control of the instrument.

In most cases it will suffice to set up the microscopes with the demonstration material already centered and focused, and have the students look at the preparations.

Chromosomes, if they are to be seen, must not be searched for in fresh preparations. If desired, prepared slides may be made or purchased, — as, for example, root-tips of onion.

If it is not feasible to place protozoa and living tissues under the observation of the students, for the purpose of forming a definite idea of the appearance of protoplasm, it is often worth while to prepare an emulsion of oil and salt water. This emulsion exhibits constant movements of a kind that are in some ways similar to those seen in living protoplasm; and while the students may not know anything of surface tension, they do know that "oil and water will not mix," and that the movements in the emulsion are due to the "unmixing" of the oil and water.

References. LOCY, W. A., Biology and its Makers, chap. xi; LOEB, JACQUES, The Dynamics of Living Matter, chap. iii; WILSON, The Cell, chap. i.

VI. THE CONDITIONS OF LIFE

Before beginning the study of the relation between the environmental factors and life processes, it is well to make an inventory of what the members of the class already *know* on the subject. We shall find many beliefs that are unsupported, many that will not stand critical examination. On the other hand, it is not worth while to demonstrate anew what is already well established for all of us.

By contrasting the conditions that obtain in a jar containing seeds that do not sprout, with the conditions in the ground, where seeds do sprout, we are enabled to analyze the environment for the purpose of selecting the significant factors, or for the purpose of formulating hypotheses that can be subjected to experimental test. The fact that seeds behave in one way in the storage bin and in quite a different way in the soil furnishes the occasion and the opportunity for seeking in the sprouting conditions of seeds the answer to our general question.

Have a list of all the suggested factors made on the board; check out those that are the same for seeds in storage and seeds in the soil. There will be left for immediate experiment hardly anything more than water; for although other factors may be related to the sprouting, they appear to be the same for the resting seeds and for the developing embryos. Before proceeding with any experiments, therefore, it is well to emphasize the idea that, while we are seeking for *single* determining factors, we must be prepared to consider the possibility of a determining *combination* of factors.

Have students formulate the general problem, What is the relation of *this factor* to the sprouting of seeds? Then have a plan of campaign worked out by the class. When a satisfactory plan is agreed upon, have committees of the students arrange a demonstration series for the class; those who are in a position to do so should be encouraged to perform special experiments at home.

A satisfactory plan must include the *control*. This should appear in the course of the discussion; the teacher should avoid presenting the idea as authoritative or as standard practice.

Whatever plan is used for determining the relation of moisture to sprouting, occasion should be found or made for introducing the problem of *quantity*, — Does an increase in moisture accelerate the process? This should offer opportunity for experimental demonstration leading to the idea of the *optimum*.

Have reports of the experiments made out in good form (see p. 8), and so far as possible have data presented in tables. For

example, the conditions and results of the experiment can be presented in tabular form, or the results on successive days may be tabulated.

After the students have formulated their conclusions as to the relation of moisture to sprouting, it is in order to take up some of the factors that have been laid aside as being the same in the two contrasted situations. For example, What is the relation of air, of temperature, of light, to sprouting?

As before, have the problems and the plans formulated by the students, giving suggestions only where necessary, yet not unduly prolonging the preliminaries.

Differential air conditions may be obtained by using vessels of different sizes for a given number of seeds or by placing different numbers of seeds in a series of vessels of the same size. Of course the seeds are to be soaked in water in advance, since we know that moisture is essential. Another method would be to exclude different amounts of air from bottles of the same size, by means of soil or plaster of Paris. A practical vacuum may be obtained by inverting a test tube full of mercury into a mercury bath (avoiding the entrance of air bubbles), and then carefully slipping in a few soaked peas. The tube may be held in place with a clamp on a ring stand.

For differences in temperature use a refrigerator, the classroom and the boiler room, or a place close to the radiator or stove. The difficulty of obtaining constant temperatures of three or four grades would usually preclude this experiment. Where ovens or incubators with thermostats are available, the experiment is well worth performing.

Problems as to light and other factors may well be left to the initiative and ingenuity of individual pupils who are especially interested. It is well to have the experiments performed according to different methods, and to have the results compared and discussed in class. For example, in the experiment on the relation of moisture to sprouting, some may use soil, others sand, or sawdust, or blotting paper, and so on; while in one series the glass vessels, the water, and the seeds are used without any matrix.

References. ANDREWS, E. F., Practical Course in Botany, pp. 10–12, 30–40, chap. vii; BERGEN and CALDWELL, Practical Botany, pp. 139–141; BERGEN and DAVIS, Principles of Botany, chap. i; COULTER, J. M., Elementary Studies in Botany, pp. 174–176; DUGGAR, B. M., Plant Physiology, pp. 280–296, chap. xv; MORGAN, T. H., Experimental Zoölogy, chap. i; OSTERHOUT, W. J. V., Experiments with Plants, chap. i. Morgan is for the teacher only; in the others will be found many suggestions for individual experiments and projects for pupils.

VII. AIR AND SOIL IN RELATION TO SPROUTING

To show which of the gases in the air is related to sprouting, prepare flasks of carbon dioxid, of nitrogen, and of oxygen, with seeds that have been soaked in water. The control consists of a flask of the same size, containing the same number of seeds but ordinary air instead of any special gas. All the flasks are sealed with paraffin, and they are kept together for the sake of the uniform temperature and light. It is well to *wash* the gases used in this experiment by passing through clean water in a bottle connected as shown in Fig. 4.

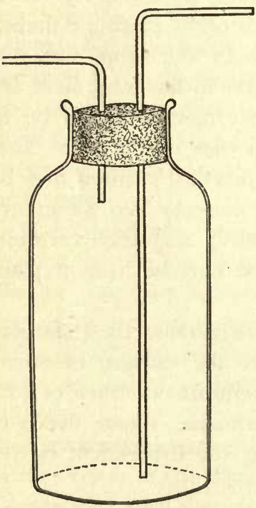

FIG. 4

We can test the gases left in the flasks wherein the seeds sprouted, for an increase in the amount of carbon dioxid.

To show that the sprouting seeds give off heat, fill two large bottles with seeds that have been soaked for twenty-four hours; to the contents of one of the vessels add a little formalin, to kill the seeds without altering their appearance. In each bottle insert a thermometer; and if a third thermometer is available, have that in the air beside the bottles. Place the two bottles together in a suitable box and pack in with cotton waste, sawdust, or other material, to prevent rapid change of temperature. Read the thermometers from time to time and have the results tabulated. Under

favorable conditions there should be a difference of several degrees (centigrade) between the temperature of the sprouting seeds and that of the soaked seeds that did not sprout, or the surrounding air.

Compare the sprouting seeds to other living things and to engines.

The suggestion that animals and human beings resemble the germinating seeds in that they give off heat and use up oxygen can be carried farther by testing at the same time the exhaled air and the ordinary room air in their effect upon limewater. The set of bottles shown in Fig. 5 will facilitate the demonstration.

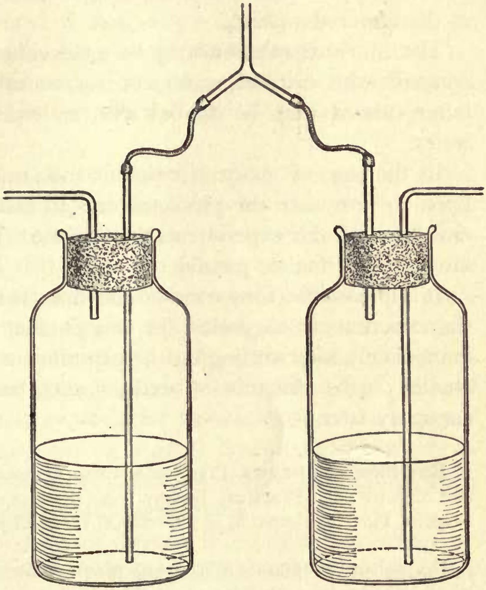

FIG. 5

When the free end of the Y-tube is used as a mouthpiece, inhalation of air draws the gas through one of the bottles, and exhalation drives the gas through the other bottle. Limewater placed in both bottles will show the difference between inhaled air and exhaled air very strikingly

Have the idea of soil analyzed into sand and other insoluble constituents, salts, and organic remains. Since the salts appear to be the factors most likely to influence the plants, the experiments would center about them. After formulating the problems and making the plans, arrange to grow seedlings in clean sand moistened with *pure* water; that is, water free from dissolved matter. Use distilled water and explain how the purity of this differs from the purity of pure drinking water. As a control, make a

parallel growth in garden soil, and another in clean sand moistened with tap water, well water, or the like, or a special solution known to contain salts.[1] A comparison of the condition of the plants after a prolonged growth, or at the time when some begin to show evidence of deterioration, will throw light on the relation of soil salts to the life of the plant.

The nutritive solution may be used either as root medium (in contrast with distilled water) or for watering the sand. In the latter case it may be diluted with an equal volume of distilled water.

In the case of every experiment the students should be called upon to formulate the problems and to indicate at least the general form of the experimental procedure. The results should be tabulated so far as possible.

It is impossible, for a considerable time, to draw conclusions from the experiments suggested for this chapter; it is therefore well, immediately after setting up the experiments, to undertake further studies on the structure of seeds, coming back to conclusions and summary later.

References. ANDREWS, Practical Course in Botany, pp. 30–40; BERGEN and CALDWELL, Practical Botany, pp. 447–448; COULTER, Elementary Studies, Part II, chaps. ii, iii; DUGGAR, Plant Physiology, chaps. vii, viii.

[1] A culture medium for growing plants without soil may be prepared by dissolving in each liter of distilled water

Potassium nitrate	1.0 gram
Calcium sulfate	0.5 gram
Calcium phosphate	0.5 gram
Magnesium sulfate	0.5 gram
Sodium chlorid	0.5 gram
Ferric chlorid, or ferrous sulfate solution	A few drops

Another formula for a nutritive solution is the following: To each liter of distilled water add

Calcium nitrate	1.00 gram
Magnesium sulfate	0.25 gram
Potassium chlorid	0.25 gram
Monopotassium phosphate	0.25 gram
Iron solution	A few drops

VIII. SEEDS AND SEEDLINGS

For the study of seed structure, kidney beans, pumpkin or squash seeds, large peas, and corn will furnish convenient illustrative material. Seeds to be taken apart should be soaked at least twenty-four hours; a few drops of formalin in each jar containing soaked seeds will prevent decomposition.

For the study of the main parts of a plant, any small weeds that can be pulled up by the roots and gathered in quantities may be used.

In making drawings of structures studied, we should avoid, on the one hand, hasty and careless sketches that do not really show the significant features, and, on the other hand, elaborate and artistic drawings that show too much, often concealing the significant features amid a mass of unessential detail. To make large, clear, diagrammatic figures that show forms and relationships is a trick worth cultivating. It is worth while to suggest convenient methods of arranging and labeling drawings, as well as suitable lettering and location for names, dates, class designations, etc. But it is easy to lose a great deal of time in elaborating on these details, and a great deal of energy in insisting upon uniformities that are in the end unimportant.

Where the students take an interest in classification it may be suggested that a committee prepare a chart with three columns, on which are to be entered the names of plants as they come to the attention of the class, according to the number of cotyledons in the seeds. This device will tend to place the more familiar seed plants in their main divisions, and will also help to fix the idea that there are many plants that never bear seeds.

Collections of economic seeds should be encouraged, and some should be made for the school museum.

The experiments on the relation of the accumulated food in the seed to the life of the young plant are easily performed by the students themselves or may be done in the laboratory for demonstration. After sprouting soaked corn grains, the bulk of the endosperm is cut away and the hypocotyl is passed through a

small hole in a piece of cheesecloth or muslin stretched over the top of a bottle or tumbler filled with water. Pea seedlings with the cotyledons removed are arranged in a similar way. The control consists of the seedlings with the endosperm or cotyledons undisturbed. Fig. 6 shows the results of such experiments.

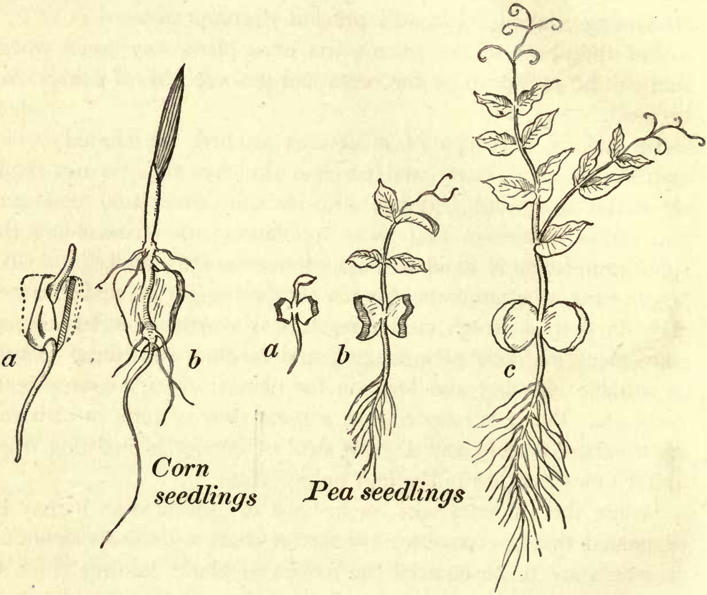

FIG. 6

To discover whether there has been any loss of material from the cotyledons of the growing plantlets, dig up seedlings that have been grown in sand or soil, and compare with the cotyledons of fresh-soaked seeds.

Seedlings should be started in flat boxes of soil or sand (or sawdust) at intervals of two days for two or three weeks before they are to be used. They will serve for comparative study of structure and of emergence.

References. ANDREWS, Practical Course, pp. 40–47; BERGEN and CALDWELL, Practical Botany, pp. 136–144; BERGEN and DAVIS, Principles of Botany, chap. iii; COULTER, J. G., Plant Life and its Uses, pp. 348–353; COULTER, J. M., Elementary Studies, Part II, chap. iv; COULTER, BARNES, and COWLES, Textbook of Botany, pp. 270–275 (for the teacher); OSTERHOUT, Experiments with Plants, chap. i.

IX. EXTERNAL FORCES AND PLANTS

The demonstration of geotropism with the aid of the centrifuge or the clinostat is not satisfactory for high-school students who have not yet studied physics, since it involves the identification of centrifugal acceleration with gravity. To get this clearly requires too much digression. It is better to use an arrangement that permits the inversion of the seedlings from time to time.

A convenient arrangement for the study of geotropism consists of two panes of glass (any size will do), one serving as a base and the other as a cover. The bottom glass is covered with cotton wool or wrinkled filter paper, upon which soaked seeds are placed. In placing the cover on top of the seeds, it is well to insert bits of cork under the corners, to prevent crushing the seeds. The two panes are held together by means of rubber bands. The wet cotton or paper extends beyond the end of the glass. The whole arrangement is set up vertically in a shallow dish containing a little water in the bottom. The cotton or paper protruding beyond the top of the glass is turned back into the water. In this way the absorption of water to keep the seeds moist is not altogether from below. After the seeds have sprouted, the position of the hypocotyls is noted, and every day or two the glasses are turned over.

Students can be interested in carrying out this experiment at home. If there are not enough suitable pieces of glass available, the bottom can be made of a piece of thin wood. By using small seeds (radish, flax, or mustard) and blotting paper, enough moisture can be supplied without extending the absorbing material beyond the edge of the glass. The edges may then be loosely inclosed with dry paper, to prevent excessive evaporation.

If the material is kept in condition long enough, the negative geotropism of the shoots can also be demonstrated. In making experiments with the geotropism in shoots of older plants, be careful to avoid one-sided illumination.

In the experiment on the geotropism of the root, it should not be difficult to make the class see that downward growth is something different from falling down; occasionally, however, a student becomes confused on this point. In such a situation the fact that the pressure of the root downward is far in excess of the weight of the plant may be conveniently shown by making a hypocotyl penetrate into mercury. Windsor beans are convenient for this experiment, and the sprouted seed is pinned to a cork fastened over the dish of mercury, with a little water over it, as shown in Fig. 7.

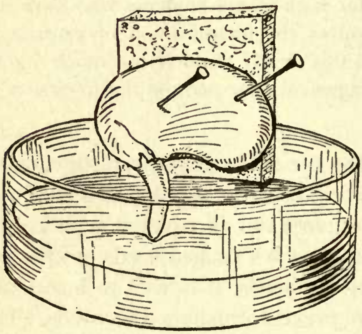

FIG. 7

An ingenious device for actually measuring the downward pressure of a root is described in Osterhout's "Experiments with Plants," pp. 81–85. See also Ganong's "Plant Physiology."

To demonstrate the growth movements in roots, use peas that have been allowed to sprout in moist paper, having fairly straight hypocotyls about an inch long. Mark off intervals of about 1 mm. from the tip of the root, using india ink and a scale. For applying the ink use a very fine pen or a bow made of a horsehair or a fine silk thread stretched between the ends of a piece of spring steel. Replace the young plants among the folds of moist paper, with the tips in a horizontal position but free to bend down. The results after a day or two will show not only the region of maximum growth in the tip of the root, but also the fact that the curvature is brought about by more rapid growth on one side than on the opposite side.

The response of plants to light stimulation may be shown by comparing plants grown in different degrees of illumination, or by watching the behavior of plants exposed to one-sided illumination. For the first experiment divide a lot of seedlings of about the same stage of development into two sets. Cover one set with a pasteboard box that will effectually exclude the light without excluding adequate ventilation. In the course of a few days it will be possible to see differences in the height of the two groups. In a few days more it will be possible to observe the blanching of the plants deprived of light. It is fair to conclude from these results that light retards the growth of plants, and that the green of the plant can be maintained only in the presence of light. Emphasize the fact that darkness is a *negative* condition; it is not darkness that makes plants grow faster, but light that retards the growth.

Plants grown in flowerpots inside the window will frequently present the effect of one-sided illumination, in that the leaves will be turned with the flat surface parallel to the window or with the tips inclined toward the window. Geraniums are very good for this. To show that the position of the leaf is not a random one, the pots should be turned through an arc of 180 degrees and the positions marked, on successive days. Have students look up "compass plants" and bring in evidences of phototropism from field and garden or from house plants.

It is not worth while to demonstrate chemotropism, although any students who are sufficiently interested to do so should be encouraged to work out plans and carry out experiments by themselves, and report to the class.

Hydrotropism is easily demonstrated. Fill a small flowerpot or a Zurich germinator with sphagnum, kept moist. On the outside of the pot place some mustard seeds, which will adhere because of a mucilaginous substance they secrete. Suspend the pot under a bell jar or a large battery jar. The roots, instead of growing down, will cling to the moist surface of the pot. The control consists of an identical arrangement in a jar containing a vessel of water, to keep the atmosphere saturated; in this jar the roots

will grow downward. Another arrangement consists of a wire basket filled with wet sphagnum or excelsior, in which the seeds germinate. After the roots have projected beyond the basket, suspend the latter with the bottom inclined, so that the nearest water for each root is not down but to one side. This should be placed under a jar, to prevent drying of the roots.

References. For the teacher: COULTER, BARNES, and COWLES, Textbook, pp. 458–479; DARWIN, CHARLES, Movement in Plants; LOEB, Dynamics of Living Matter, Lect. VII, VIII. For the pupils: ANDREWS, Practical Course, pp. 47–52; COULTER, Plant Life, pp. 131–134; DUGGAR, Plant Physiology, chap. xx, pp. 415–420; OSTERHOUT, Experiments, chap. ii.

X. ABSORPTION FROM THE ENVIRONMENT

To introduce the subject of osmosis, it is well to begin with practical demonstrations of diffusion. Open a bottle containing acetic acid, ether, chloroform, alcohol, formalin, or some other substance with a decided odor. Open the gas cock for a few moments. When it is evident that the odorous substance has reached some distance from its source, the subject of diffusion may be taken up.

For diffusion in liquids, prepare some bottles or tumblers of water and place in each a lump of sugar or salt. Into a beaker or jar of water that has been standing for some time, so that there are no movements or currents in it, let fall a drop of red ink (eosin solution or some other water-soluble pigment will do). The diffusion of the salt or sugar, and that of the ink, are visible and demonstrate the action of some form of attraction that, in the one case, raises the material from the bottom of the jar to the surface of the water (since in time the diffusion will result in an equal distribution of the material throughout the liquid), and in the other case spreads it through a quiet body of water.

To illustrate absorption without diffusion, sheets of glue or of gelatin may be used. Wood, leather, and paper behave in much the same way, except that the glue and gelatin are practically homogeneous substances, whereas the other materials represent structures with visible (microscopic) pores.

An artificial root hair or cell may be made of goldbeater's skin or of celloidin. The latter is to be preferred because it gives a homogeneous membrane that the students can see in the course of formation. Use a pure celloidin dissolved in alcohol and ether, free from acetone. Pour a little of the celloidin into a clean, dry bottle (4-oz. wide-mouthed) and then slowly pour out what you can (back into the original container), turning the bottle all the while so as to spread the celloidin evenly over the inner surface of the bottle. Allow to stand for several minutes, blowing into the bottle from time to time, to accelerate the evaporation of the ether and alcohol. Prepare for each bag a two-hole rubber stopper (size No. 4 or No. 5), a thistle tube, a rubber band, and a glass plug to fit into one of the holes in the stopper. There will also be needed a mixture of sirup or molasses and water, a jar of clean water, and a support.

After all of the ether has evaporated from the "newskin" membrane in the bottle (as you can tell by the odor), add a little water, which will accelerate the removal of the alcohol. With a little careful manipulation it is possible to remove the bag from the bottle without breaking it. Insert the rubber stopper in the neck of the bag, and make fast with a few turns of the rubber band. Insert the thistle tube, and the bag is ready to be filled with the sirup. After a little practice the teacher should be able to make the bag in a few minutes, and thus to complete the whole operation in the presence of the class.

After pouring in the sirup until the bag is quite full, plug the vent, wash off the outside, and place in the jar of clean water, suspending the cell so that it does not come in contact with the sides of the jar. Note the height of the liquid on the inside, and watch the rise of liquid in the thistle tube. If it is desired to continue the rise of liquid beyond the limits of the thistle tube, this should be replaced by a long glass tube — say three feet long — before closing the vent and clamping in place.

Parallel demonstration of starch paste, various salts and sugars, or of different concentrations of salts and sugars may be made by different members of the class. The diffusion outward should not

be overlooked in the presence of the striking inward diffusion of water. The discussion of the results should bring out all the important facts associated with the idea of osmosis.

Examples of diffusion and of osmosis in everyday experience, with practical applications, should be called for and recorded.

References. For the teacher: COULTER, BARNES, and COWLES, Textbook, pp. 297–311; LOEB, Dynamics of Living Matter, lect. iii. For the pupils: ANDREWS, Practical Course, pp. 52–58; BERGEN and DAVIS, Principles, chap. v; COULTER, Plant Life, §§ 35–36; DUGGAR, Plant Physiology, chap. iv; OSTERHOUT, Experiments, chap. iii.

XI. ROOTS OF PLANTS

To obtain root hairs suitable for class study, place radish seeds on wet blotting paper (blue or green) in Syracuse watch glasses or Petri dishes two or three days before they are to be used. There should be no free water standing above the blotters. Have dishes, with magnifying glasses, ready to pass out at the beginning of the study. As the root hairs shrivel up on exposure to the air, the dishes should be taken up again at the conclusion of the study, and stacked up for use with another class. If carefully handled, the preparations should serve two or three days. Have root hairs of tradescantia, flax, or radish mounted for examination through the compound microscope.

Fresh woody roots, as well as the fleshy roots mentioned in the text, should be on hand for examination, unless it is feasible to study them in the woods or fields.

Have on exhibition preparations for microscopic views of the principal kinds of root tissue, including the two kinds of growing tissue, — cambium and terminal meristem.

To show the dependence of root-hair formation upon external conditions, keep roots of seedlings in water, with parallel growths in sand or paper. Those in the water will not form hairs.

To demonstrate sap pressure or root pressure, take a vigorous hydrangea plant with stem at base about half an inch thick, place pot and base of plant in pail of water, and in this position cut off the stem about two inches from the surface of the soil. Connect

the stem with a glass tube by means of a rubber-tube coupling. Remove from the water and arrange a support for the long glass tube. The preparation is made in water to prevent the entrance of air-bubbles.

To get adventitious roots, place various twigs, bits of begonia leaf or bryophyllum leaf, leaves of india-rubber plant or of English ivy in bottles of water.

References. BERGEN and CALDWELL, Practical Botany, chap. iii; BERGEN and DAVIS, Principles, chap. iv; COULTER, Elementary Studies, Part I, chap. xiii; COULTER, Plant Life, chap. iv; COULTER, BARNES, and COWLES, Textbook, pp. 311–316; DUGGAR, Plant Physiology, chap. iii; OSTERHOUT, Experiments, chap. iii; United States Department of Agriculture yearbooks; farmers' bulletins.

XII. WHAT FOOD IS

The idea of activator as something needed to keep a process going may be illustrated by the spark in the gasoline engine. The drop of acid added to water to make the latter a conductor, as in hydrolysis, takes no part in the main process, but makes the latter possible.

Regulator is illustrated by the pendulum of a clock and by the balance wheel of a watch. If we place salt in the water before cooking corn meal or oatmeal, we thereby regulate the temperature at which the water will boil, since salty water has a higher boiling temperature than pure water. The gyroscope is another example of a mechanical regulator.

The school museum should gradually accumulate specimens of foods in a pure state, — casein, albumens of various kinds, and other proteins may be obtained in the market. Starches, sugars, and fats, with the sources indicated on the bottles, are helpful in making the terms stand for something concrete, and in correlating with geography on the one hand and with domestic science on the other.

References. COULTER, Plant Studies, pp. 41–42, 343–347; COULTER, BARNES, and COWLES, Textbook, pp. 356–363; HOUGH and SEDGWICK, The Human Mechanism, pp. 86–95.

XIII. THE ORIGIN OF FOOD

For conducting the experiments in photosynthesis, hydrangea, coleus, and geranium are convenient plants to use.

To show the relation of air to starch-making, exclude the air from a leaf upon a vigorous live plant, by smearing vaseline over both surfaces, *on one side of the midrib only.* After exposure to bright sunlight for a whole day, remove the treated leaf, to be tested for the presence and distribution of starch. To remove the chlorophyl and to fix the starch, boil in water a few minutes, then place in alcohol. The bleached leaf is tested for starch by placing in a solution of iodin in 10 per cent solution of potassium iodid, about the color of weak tea. It is necessary to explain that starch is the only substance known to turn blue with iodin.

The question as to which of the three chief gases in the air is concerned in starch-making could be answered by means of an experiment, if it were desirable to do so in the laboratory. Large bell jars connected with aspirators for drawing a current of air through are used. A live potted plant is placed in each jar. The inlet pipe of one jar is connected with a wash bottle containing caustic soda solution, to withdraw the carbon dioxid; a second jar is thus connected with a phosphorus container for removing the oxygen; a third has both of these gases removed. The control is allowed to get the ordinary atmospheric mixture of gases.

The relation of light to photosynthesis may be demonstrated either by using two plants, one in the light and one in the dark, or by shielding a portion of a leaf from light while the rest of the plant is exposed. The latter method is attained by pinning two pieces of black paper on the opposite sides of a leaf so as to exclude the light from the covered portion without excluding the air, and leaving the rest of the leaf exposed to light as well as to air. At the close of the first sunny day the leaf is removed from the stem, boiled in water, and soaked in alcohol. The application of iodin brings out the distribution of starch.

To show that oxygen is liberated during photosynthesis, place a healthy potted plant under a large bell jar (with an opening at the

top) on a plate of glass. Seal the base of the bell with vaseline. Remove the oxygen from the jar by burning a taper lowered from above. Seal the top opening. At the close of one or two sunny days, open the top and lower a lighted taper into the jar. The difference between the burning conditions at the beginning of the experiment and the burning conditions at the close points to the entrance of oxygen, and the plant is the only apparent source of the new gas.

To explain the general chemical relations of the materials involved in photosynthesis, it is not necessary to elaborate much detail. It is sufficient to bring out the fact that the hydrogen-oxygen ratio in carbohydrates is the same as that in water, and that the utilization of water and carbon dioxid as the sources of the elements entering into the carbohydrates leaves a surplus of oxygen corresponding to that brought in with the carbon dioxid.

In connection with this study, the results may be recorded in a table showing the parallel between photosynthesis and a manufacturing process. It is interesting, if there is time, to bring out at this point our ultimate dependence upon the sun for all the energy that we utilize, — fuels and waterfalls as well as organic processes. "Every action is a transformed sunbeam."

References. For the teacher: COULTER, BARNES, and COWLES, Textbook of Botany, pp. 363–380; DUGGAR, Plant Physiology, chap. ix. For the pupils: ANDREWS, Practical Course, pp. 168–174; BERGEN and CALDWELL, Practical Botany, pp. 15–17; BERGEN and DAVIS, Principles, pp. 107–110; COULTER, J. G., Plant Life, pp. 43–44, 228–234; COULTER, J. M., Elementary Studies, Part I, chap. iii; OSTERHOUT, Experiments, pp. 182–203.

XIV. THE CHEMICAL CYCLE OF LIFE

Have specimens of clover, alfalfa, partridge pea, or other wild or cultivated legume pulled up for a study of the tubercles. The balanced aquarium can be studied profitably with reference to the essentials of the balance. Encourage students to represent their ideas of the "cycles" etc. diagrammatically.

Have students bring news items bearing on the current or local status of the nitrogen problem.

References. BERGEN and CALDWELL, Practical Botany, pp. 374–378, 447–451; BERGEN and DAVIS, Principles, pp. 231–235; DUGGAR, Plant Physiology, chap. x; SEDGWICK and WILSON, General Biology, chap. xvii; STILES, Human Physiology, pp. 25–36.

XV. THE SOIL AS THE SOURCE OF OUR MATERIALS

The purpose of this chapter is to combat, on the one hand, general indifference toward the problem of soil use and conservation, and, on the other hand, a certain fatalistic Malthusianism. We should make clear that population and prosperity are directly related to the amount and character and condition of the soil; and that applied science can help us extend our power and resources indefinitely, without thought of exploiting the lands of other peoples. Have students gather data on reclamation, irrigation projects, etc., and data as to increased production per capita and per unit of area.

References. See references to VII; DUGGAR, Plant Physiology, chap. vi.

XVI. THE LEAF AS STARCH FACTORY

The concept *leaf* should include more than the familiar types. It is better to examine cursorily a large number of varieties than to study minutely a few forms. All the extremes afforded by the resources at hand — from the rhubarb to the asparagus, from the cactus to the cedar, from the mullein to the tradescantia — should be brought together until the student is quite convinced that the definition of *leaf* is not to be found in a description of a few or of many shapes.

Examine with the microscope bits of epidermis peeled from any convenient leaves, and cross sections thin enough to show the tissues and if possible the stomata.

Comparing the leaf to a factory, have students make diagrams showing the route followed by materials received from the air and from the stem until they are finally disposed of.

To measure the transpiration of a potted plant, inclose the pot and earth in rubber sheeting and weigh the whole. Weigh

again at intervals and note the loss. For a qualitative demonstration, the prepared potted plant may be placed under a bell jar; the condensation of moisture on the glass will indicate loss of water from the plant surface.

To show the pulling force of the transpiration current, insert the stalk of a healthy leaf in the end of a glass tube, and seal the joint with paraffin. Fill the tube with water and set over mercury. The rise of mercury in the tube is a measure of the mechanical equivalent of the transpiration from the leaf's surface.

Special readings and reports on insectivorous leaves.

References. ANDREWS, Practical Course, pp. 189–195; BERGEN and CALDWELL, Practical Botany, pp. 13–15, 18–20, 385–389; BERGEN and DAVIS, Principles, pp. 88–96, 102–106; COULTER, Plant Life, pp. 234–241, 251–255; COULTER, BARNES, and COWLES, Textbook of Botany, pp. 521–530, 551–578, 385–388, 616–620; DARWIN, Insectivorous Plants; DUGGAR, Plant Physiology, chap. v; OSTERHOUT, Experiments, pp. 173–181, 203–223.

XVII. OUR DEPENDENCE UPON LEAVES AND CHLOROPHYL

This is in part a repetition of the thought in XIV, The Chemical Cycle of Life, but from a somewhat different point of view. The attention is directed to the concrete materials that we actually use. Materials used in connection with the study of leaf forms and structure, and museum material, may be used here. Connect the study with the local market and industrial conditions.

For the study of algæ, there should be microscopic preparations or good charts. Homemade charts that will serve adequately can be prepared with a little effort.

This topic furnishes an excellent opportunity for a synthetic review.

References. COULTER, Elementary Studies, pp. 378–383; SARGENT, Plants and their Uses, §§ 36, 137. Yearbook of the United States Department of Agriculture, on variety, magnitude, and values of crops.

XVIII. STARCH-MAKING AND DIGESTION

Digestion of starch can be demonstrated by using a very thin starch paste, (*a*) with some takadiastase and (*b*) with some human saliva. Use large test tubes; keep at room temperature or warmer.

Demonstrate starch test with iodin on small portion drawn off at the beginning of the experiment. Draw off at intervals of five or six minutes and test again. When there is no more starch present, test portion from each test tube with Fehling solution. The disappearance of the starch and the appearance of the sugar (the absence of which may be demonstrated at the beginning of the experiment) indicate that something has happened to the starch which probably has something to do with the formation of sugar. It is well to test the diastase with Fehling solution at the beginning, since some commercial diastase contains reducing substances.

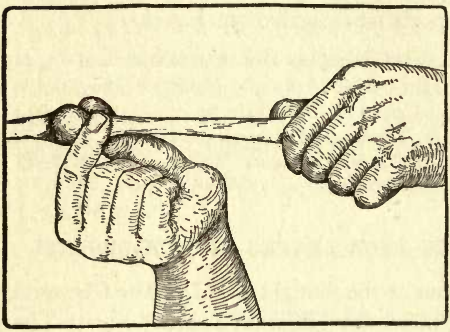

FIG. 8

A more striking and otherwise more satisfactory demonstration consists of showing the formation of diffusible substances by the action of diastase and saliva. Place the thin starch paste with saliva in a celloidin bag (see p. 31 of Manual), and starch paste with diastase in another bag. A third bag (control) contains merely starch paste. The three bags are suspended in three jars or tumblers containing clean water. After the expiration of fifteen minutes, withdraw some of the surrounding water and test with Fehling solution. Repeat from time to time until there is a positive reaction. Then put a few drops of iodin inside each bag. The bags containing saliva and diastase will have lost their starch and will have diffused sugar into the surrounding water; the control shows no change.

Corn grains that have been soaked in water overnight may be tested with Fehling solution (after being cut open, some lengthwise and some crosswise). Allow some of the soaked grains to sprout, then cut them open and test them. The presence of sugar is due to the action of a diastase upon the starch.

References. For the teacher: COULTER, BARNES, and COWLES, Textbook of Botany, pp. 397–402; DUGGAR, Plant Physiology, pp. 265–271, 277–278; GREEN, Vegetable Physiology, chap. xvi; LOEB, Dynamics of Living Matter, lect. ii. For the pupils: ANDREWS, Practical Course, pp. 6–10; BERGEN and CALDWELL, Practical Botany, pp. 144–146; COULTER, Plant Life, pp. 350–352; OSTERHOUT, Experiments, pp. 155–169.

XIX. DIGESTIVE SYSTEM IN MAN

If microscopic preparations of the tissues of the alimentary canal are available, students will be interested in examining them; but they are not essential. Specimens of fresh materials obtained from the butcher may be shown to those who are not squeamish. None of the students would probably object to examining sausage casing that has been allowed to soak in water until soft. A satisfactory demonstration of peristalsis consists of placing a marble in a long piece of sausage casing and driving it through to the other end by pulling the casing through the fingers (see Fig. 8).

Ordinarily it is not worth while to demonstrate the action of the various digestive ferments of the alimentary canal. If the notion of digestion or fermentation is clear, it is sufficient to show specimens of pepsin, peptone, pancreatin, ox-gall, etc.

A good way to summarize this study is to have students make a simple diagram representing the alimentary canal, and to label it with the names of the organs on one side of the drawing, and the names of the processes involved on the opposite side.

Have students prepare a table like the one below, and fill in all the blanks:

THE ACTION OF DIGESTIVE JUICES ON FOODS

	ACTIVE JUICES	FOODS DIGESTED	RESULT OF ACTION
Mouth			
Stomach . . .			
Intestines . . .			

Another form of summary is to have students describe the fate of an imaginary mouthful of food containing all the nutrients, in its course from the mouth to the large intestine.

References. HOUGH and SEDGWICK, The Human Mechanism, chap. viii; STILES, Human Physiology, chaps. xiii–xv; STILES, Nutritional Physiology, chaps. xiv–xvi. Have pupils make special reports on digestive systems and on special organs of various vertebrate and invertebrate types or groups.

XX. HEALTH AND FOOD STANDARDS

It is important to establish a clear distinction between standards that represent customs or usage, and norms established as the result of experiment or measurement. Have students present examples of usage among certain people who have remained behind the best thought and knowledge of the same or other communities. Get them to think of the reasons for this, and of methods for accelerating the standardization of practice.

Get examples of food fads or other standard usages, with the principles offered in justification.

Determining units for measurement; get examples of as many kinds as the students happen to know. As a demonstration, determine the time needed to raise a quantity of water to the boiling point in a given vessel, with the burner in use; compare with results when using double quantity of water. Or use similar quantities with different size of flame.

Explain principle of calorimeter; if there is one in town, arrange to visit with the class and have its workings demonstrated.

Study cases in which standards have come into general use after scientific determination.

In the matter of food standards, bring out the principle of individual variation. This should be referred to as occasion offers, as one of the fundamentals of modern thinking about organic and social problems.

To give the daily requirements more concrete significance, have the students calculate the mechanical equivalent of the energy represented by the daily ration. For example, compare the energy consumed by the organism in one day with the moving of a ton of freight, with the raising of passengers in an elevator a given height, with the lifting of a quantity of ore or bricks, and so on.

The mechanical equivalent of one calorie is about 3,060 foot-pounds. One horse-power is 550 foot-pounds per second.

References. HOUGH and SEDGWICK, Human Mechanism, pp. 211–217; ROSE, Feeding the Family, chap. i. The teacher should constantly consult publications of research laboratories, such as those of Mendel, Lusk, Chittenden, Benedict, etc. See United States Bureau of Standards, *Circular No. 55*.

XXI. FOOD REQUIREMENTS

Have each student prepare a schedule of one meal, or of a day's meals, and then go through the calculations according to the methods used in the text. After the calculations are finished, have the food assortments of specimen charts criticized by the various standards. Have students formulate their own suggestions for the improvement of their diet, — as, eat less; eat less fat or protein; eat more vegetables; and so on.

References. FISHER and FISK, How to Live, pp. 28–35; HOUGH and SEDGWICK, Human Mechanism, pp. 217–233; LEE, ROGER I., Health and Disease, pp. 31–45; ROSE, Feeding the Family, chap. iii; STILES, Human Physiology, chap. xxv. Current publications. Have special reports made on rations for soldiers or for various institutional groups.

XXII. FOOD AND DIETARIES

It would be interesting and illuminating to collect examples of superstitions, folklore, and family traditions on what to eat and what to avoid. Misleading suggestions on the choice of food are frequently found in advertisements of special food preparations, and in more dogmatic forms. Many obscure pathological conditions have come to be recognized in recent years as due to disturbances in nutrition that may be corrected through proper adjustment of the diet. The students should be encouraged to note and report experiences and observations bearing on these points. Where there is an opportunity to correlate the study of food with the domestic-science work of the school, this should not be overlooked.

In the study of food economy there is an opportunity for a great deal of practical work, and this is readily correlated with the domestic science. Using Fisher's tables, have students obtain

current prices of the various foods, and calculate the cost of standard (100 calorie) portions. An interesting piece of outside work consists of preparing a series of bottles or specimen jars showing the standard quantity of each of a series of food articles, together with the price of each. A parallel series might be prepared by another group of students, showing the quantity of each kind of food that may be obtained for a given amount of money, — say ten cents or five cents. The labels on these jars should contain, of course, all the significant data, as in the two labels below:

SERIES A	*SERIES B*
TEN CENTS' WORTH	100 CALORIES
OF	OF
CORN MEAL	OYSTERS
Quantity	Quantity . . . .
Calories	Protein . . . .
Protein	Cost . . . .
Prepared by	Prepared by . . . . . .
Date	Date . . . .

Dry food materials need merely to be sealed in the jars or bottles. Meats, fish, fresh vegetables, etc. can be preserved in 4 per cent formalin solution. Each student need prepare but one or two specimens; and the information gathered is exchanged by comparison of costs and other data. The specimens may be kept indefinitely, and the collection may grow from year to year.

References. FISHER and FISK, How to Live, pp. 35–40; HOUGH and SEDGWICK, Human Mechanism, pp. 233–243; JORDAN, E. O., Food Poisoning, chap. ix. LEE, Health and Disease, pp. 54–68, 46–51; RAPEER, Educational Hygiene, pp. 68–77. Special readings in ROSE, Feeding the Family. Have students compare special rations established for domestic animals, from reports of agricultural experiment stations and from the United States Bureau of Animal Industry. Current matter on vitamines and on deficiency diseases. See XX.

XXIII. FOOD HABITS

The practical value of these studies should of course issue in habits, — habits of attitude as well as habits of conduct. It is, however, extremely difficult to gauge the extent to which the studies have influenced the habits of the pupils. With discretion a teacher may from time to time put forth a question or a suggestion that will bring an illuminating reaction on this problem.

For a study of the teeth, it is usually easy to obtain instructive specimens from a dentist. Cross and longitudinal sections may be prepared by means of a grindstone. But it is easy to spend too much time on the study of tooth structure and form; these are not worth much unless it is desired to make a fuller study of comparative morphology of mammalian teeth. The important facts are few and quickly grasped, and are related to *decay*.

A striking demonstration of the danger of exposing the teeth to rapid alternation of temperature consists of heating a test tube and then casually dipping it into a jar of cold water.

It has been found very instructive to make a census of the proprietary drugs on sale or advertised in the neighborhood, for the purpose of determining the proportions of those offered as remedies for headaches and constipation. Labels or wrappers from such preparations make an interesting exhibit.

References. FISHER and FISK, How to Live, pp. 44–51, 51–57, 78–89; HOUGH and SEDGWICK, Human Mechanism, chap. xix; LEE, Health and Disease, pp. 51–53; ROSE, Feeding the Family, chap. ii; STILES, Human Physiology, chap. xxvi; STILES, Nutritional Physiology, chaps. xxii, xxiii. Special readings in JORDAN, Principles of Nutrition, and in SHERMAN, Chemistry of Food and Nutrition. Teacher should be familiar with work of Cannon and of Carlson. See CANNON, Bodily Changes in Pain, Hunger, Fear, and Rage, chap. i.

XXIV. THE SOCIAL SIDE OF THE FOOD PROBLEM

Have the students find out the local situation in regard to the protection of the water supply, and classify the functions involved in this protection in order to see how much depends upon biological principles.

Have the students obtain copies of local regulations concerning food standards, food protection, and food sales. Reports of the state and municipal departments of health, bureaus of weights and measures, milk committees, etc. should be consulted.

Collect labels from various food packages, showing the publication of facts concerning preservatives, artificial coloring, etc., in accordance with specified laws, or of claims as to purity of materials used. It is impossible to know ordinarily the extent to which food is "faked." But reports are constantly appearing that throw light on this question, and students should know both how to obtain the information contained in such reports and how to interpret it. For example, the New Hampshire Board of Health issued one report in which it appeared that of three hundred and sixty-three samples of food taken in the market, nearly one half (164 = 45.2 per cent) were adulterated. Changes in the attitude of official and semiofficial bodies toward this matter are constantly being made, and students should know how to keep in touch with such changes. For example, in New York City the Board of Health began in 1914 to publish every week the names of all dealers or manufacturers convicted of selling foods not in accord with official standards. The plan of publishing names and addresses of violators has been especially valuable in connection with the milk business, since the ordinary milk buyers are practically helpless in their dealings with unscrupulous sellers. Newspaper clippings should be pasted in notebooks or posted on the class bulletin.

Have students report on conditions in stores and markets where food is sold. After comparing notes in class, have them draw up a scale for scoring or grading the shops.

Have students report on conditions in workshops, stores, factories, and offices, in relation to lunch-rooms, opportunity for washing up, etc. Much of this information can be obtained by inquiry among relatives and acquaintances.

Where there is a school lunch service, it should be possible to coöperate for the purpose of establishing in the minds of the pupils standards in regard to conditions as well as in regard to the food, balanced rations, quantities, etc. Have students prepare schedules

of food values for the various items served in the lunch-room, and arrange to have the figures used in connection with the menus. If this is already the practice, sample menus may be used as basis for discussion of balanced rations etc.

Where there is time, it is worth while to devote a whole period to the subject of National Food Resources. Begin with a comparison of the proportion of the population engaged in farming at the close of the Civil War with the proportion so engaged at the time of the last census. Then compare the per capita production of various food materials at the two periods; compare the yield per acre under cultivation, and so on. The point to be brought out is the *increased control* and the *increased resources* through the application of biological and other exact knowledge. Assign individual students to report on the various governmental activities related to the food yield that are mentioned in the text. Bring out the realization that the problem of food conservation means more than adequate production; it involves matters of transportation, marketing, storage and preservation, and, finally, adequate *distribution* in the economic sense, — that is, the ultimate consumption of the food in a way that will contribute the utmost to the welfare of the nation or the community.

References. HOUGH and SEDGWICK, Human Mechanism, pp. 505–514; JORDAN, Food Poisons, chaps. v, vi, viii; LEE, Health and Disease, pp. 69–73. Special reports on war food administration; on local and state regulations of food production, food distribution, and food standards; on current studies pertaining to character and extent of malnutrition among children or other groups; on current or local efforts to remedy defects of nutrition in large groups. Material can be obtained from the departments of health, commerce, and agriculture, and from the United States Children's Bureau.

XXV. STIMULANTS, NARCOTICS, AND POISONS

In getting the idea of acclimatization, the students will be led to draw upon their own experiences and observations. The point to emphasize is that the modified organism becomes dependent upon the new environment. Whether it works as well under

the new conditions as it can under the natural conditions is a different question, although an important one.

The difficulty that many students have in forming chemical concepts may in part be met by the use of mechanical analogies, which are more readily visualized. For example, in thinking about the action of drugs or chemicals upon protoplasm, compare this action to the effects that may arise from introducing a foreign body into a piece of machinery. If a boy should stick his finger into the business region of a buzz-saw, the machine would keep right on working as though nothing had happened; this corresponds to an indifferent chemical body, or to a "subliminal dose." If the boy should drop a bar of iron in among the wheels, it might catch between the spokes and stop the machinery altogether; or it might catch against a moving part, simply slowing up the machinery. This corresponds to a narcotic, up to the "lethal dose." Finally, he could push his bar of iron against the belt connected with the governor of the engine and disconnect this part; in that case the engine might suddenly begin racing at increased speed. This would correspond to the effect of a stimulant, or accelerator.

References. FISHER and FISK, How to Live, pp. 64–78, 250–268; HOUGH and SEDGWICK, Human Mechanism, pp. 357–363; LEE, Health and Disease, pp. 125–134; "The Great American Fraud" (American Medical Association); *Farmers' Bulletin*, "Habit-Forming Drugs."

XXVI. ALCOHOL AND HEALTH — XXVII. ALCOHOL AND SOCIETY

We must be on our guard against the temptation to resort to the hortatory method in dealing with this subject; it is necessary to maintain a more calm and more tolerant spirit than that which characterized the campaigners of a generation or two ago. It happens altogether too frequently that intelligent, honest, and likable people are also alcohol drinkers. The awful things predicated about drinkers in the older books do not find confirmation in the daily experience of the students. Instead of discrediting the drinkers, these experiences discredit the books and the whole tribe of physiology and hygiene teachers.

There are available verified and verifiable data that help to demonstrate the undesirability of alcohol as a beverage, but these data are to be used in a common-sense way. We must avoid the fallacy of arguing from statistical generalizations to individual application. It is impossible to say "You will suffer" so and so if you drink. The very most that we can say is, "If you drink, your chances of becoming sick are increased by so many per cent; and when you are sick, your chances of recovery are reduced by so many per cent." In other words, the data show simply *group* effects. We may therefore teach only that a society, or community, or class of people stands to gain by adopting this or that course of conduct. Our problem is to socialize the interest and make the individual resolve that, so far as he is concerned, the group of which he is a member is to profit from his learning. So long as our health teaching in regard to alcohol (and in regard to many other matters) was based on the sentiment of competitive advantages for the individual, it resulted simply in placing before the child the betting odds against the practices condemned. And since most children are fairly good "sports," the teaching did not succeed in intimidating them. The individual can often afford to take chances; the only certainty we can teach from our statistical studies is that the group suffers from the use of alcohol.

To demonstrate the effect of alcohol upon proteins, add alcohol to the raw white of an egg; this is a suggestion of how alcohol may injure protoplasm. Supplement with parallel demonstration of the coagulating effect of mercuric bichlorid solution and other "poisons." The point is to show that alcohol is one of a class of substances that are unquestioned poisons, and not something unique in its relation to protoplasm.

Have students gather data on usages of local employers, in selecting workers for responsible positions, in the matter of drinking. Have them get information as to regulation of the patent-medicine trade by local or general authorities. Have reports made on fraudulent cures for alcoholism. What are the current and local developments in meeting the social requirements of the human animal that had been left to the exploitation of the alcohol

interests in the past? Agitation and legislation since the entrance of the country upon the war. The soldier and alcohol. Opportunities for special reports and studies are almost limitless.

References. For the teacher: BILLINGS, Physiological Aspects of the Liquor Problem; KOREN, Alcohol and Society. For the pupils: FISHER and FISK, How to Live, pp. 227–250; HOUGH and SEDGWICK, Human Mechanism, pp. 363–379; LEE, Health and Disease, pp. 113–125. An excellent condensed summary of all the significant data has been prepared by the D'Abernon-Newman Committee (British) under the title "Alcohol: its Action on the Human Organism." An American edition is issued by Longmans.

XXVIII. AIR AND LIFE

Review briefly the important ideas already learned on the relation of oxygen to energesis in burning. Have live plants and animals on hand for demonstration of breathing.

If drawings have been made of cross sections of the leaf, refer to them and add further notes on the path of the air exchange involved in breathing. If there are no drawings and there is not time to make any, use wall charts, blackboard drawings, and microscopic demonstration.

If the season permits, use live insects for the study of spiracles and breathing movements; otherwise use prepared specimens. Study tracheæ from microscopic mounts and from pictures and charts.

Compare live earthworms with sandworms, bloodworms, or other gill-bearing worms near the coast. Use preserved specimens of mollusks and crustaceans for comparison of different types of gills. The course of the water in breathing is easily studied in crayfish and in fish. The breathing process in frogs should also be studied in the living specimens. The test of the students' grasp of the mechanism of breathing in the frog lies in their answer to the question, "What would happen to a frog that was forced to keep his mouth open indefinitely?"

Prepare in advance dissections showing the connection between the throat and the gill slits in the fish, and between the throat and the lungs in the frog. Some of the older students can make such

dissections under direction. Preserve good preparations in 4 per cent formalin for future use.

References. BIGELOW, Applied Biology, pp. 502–503. Special reports on course of air (oxygen) in the breathing of various vertebrate and invertebrate types, from descriptions in available books on zoölogy

XXIX. BREATHING IN MAN

Obtain lungs of calf, sheep, or ox from a butcher. Use models of lungs, showing diagrammatically some of the detail structure. For making clear the mechanics of the diaphragm action, the apparatus pictured in Fig. 9 should be set up in advance. If there is a skeleton in the school, show the relation of rib curvature and rib movements to the expansion and contraction of the chest cavity.

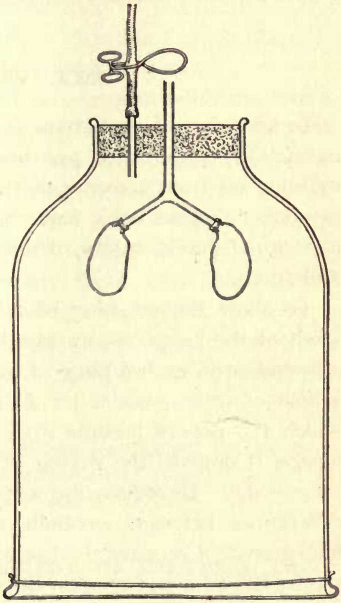

FIG. 9

A bell jar, closed at the bottom with rubber sheeting, and at the top with a two-holed stopper carrying (1) a Y-tube with two rubber balloons, and (2) a glass vent with a rubber tube closed by a pinchcock

Have students study the movements of the chest and abdominal wall with the hands while breathing slowly. Students, especially boys, are interested in comparing lung capacity. If an aspirator is available, or records from the physical-training department, compare lung capacity with chest expansion. Compare the number of breaths taken by different members of the class in one minute; individual variation; variation in *depth* of breathing of different pupils at the same time and of the same pupils at different times. Compare the number of breaths per minute before and after some vigorous setting-up exercises in the laboratory.

Demonstrate by the pupils themselves relation of posture to chest expansion, breaths per minute, tidal air. Compare notes on the effects of a tight belt or corset and other features of the clothing.

References. BIGELOW, Applied Biology, pp. 503–505; FISHER and FISK, How to Live, pp. 18–28; HOUGH and SEDGWICK, Human Mechanism, chap. x; STILES, Human Physiology, chap. xx.

XXX. VENTILATION

In speaking of ventilation standards, it is not enough to learn figures for cubic feet per hour and the like. Have students measure off from a corner of the room enough space to represent say one thousand cubic feet; have them get an idea of the cubic capacity of the classroom, of the home living-room, of the bedroom, and so on.

To show the meaning of relative humidity in relation to the work of the lungs, set up two bell jars (or inverted battery jars), suspending in each a piece of wet filter paper. Under jar *A* place a dish of water; under jar *B*, an empty dish. Note the time in which the papers become dry; that in *A* may remain moist for weeks. Compare the drying of clothes on a clear day and on a muggy day. Introduce the wet-bulb thermometer and show how differences between wet-bulb and dry-bulb readings are to be interpreted. Compare the lower temperature of the wet bulb with the feeling of a wet spot on the skin. Make clear how perspiration helps to regulate the body temperature. Use the illustration of the Australian water bottle.

Have students report on standardized usage in mines, where low oxygen pressure is maintained to prevent explosions.

Establish committees of students to be responsible for the ventilation and temperature of the classroom.

References. FISHER and FISK, How to Live, pp. 7–14; HOUGH and SEDGWICK, Human Mechanism, chap. xxviii; LEE, Health and Disease, pp. 74–83. Reports of current investigations, especially on ventilation in industrial establishments.

XXXI. CONTAMINATED AIR

The dusty trades of the neighborhood or of the community, and those that yield injurious vapors or fumes, should receive special attention. Have students find out what these industries are and what conditions prevail for the safeguarding of the health of the workers. Are there any regulations or difficulties about the contamination of the community's air by smoke or fumes?

In the study of the effects of tobacco, keep in mind the limitations of the statistical method, as suggested in the notes on Chapters XXVI and XXVII, and the further sources of error that come from the possibility of the tobacco habit being in itself largely a selective agent, as suggested in the text. In a school containing large numbers of boys it may be possible to collect data as to smoking and non-smoking, and to correlate these with physical and scholastic records. The data from your own school, or from a school in your own city or state, will carry more weight than those from some remote institution. Note especially the current and local sentiment and tendencies.

References. HOUGH and SEDGWICK, Human Mechanism, pp. 377–379; *Bulletin 231*, United States Bureau of Labor Statistics; Report of Y. M. C. A. committee on experimental study of the effects of smoking.

XXXII. FIRST AID AND HYGIENE IN RELATION TO BREATHING

Time the period during which members of the class can hold the breath. See whether those with unusually high records have any special technique that enables them to exceed the performance of the others.

Artificial respiration, by the Schaefer or by the Silvester method, should be demonstrated and practiced by the members of the class on each other. If there is an emergency hospital, a life-saving station, a fire-house, or other similar institution within reach, arrangements should be made for the demonstration of a pulmotor

or other like device for the establishment of normal respiration after asphyxiation, drowning, or electric shock.

In summarizing, make an attempt to get a survey of the prevailing habits of students and of prevailing home conditions with reference to these matters,—as open-air sleeping, mouth breathing, and so on.

References. Miners' Circular No. 5, United States Bureau of Mines; *Technical Papers Nos. 77 and 82*, United States Bureau of Mines; RAPEER, Educational Hygiene, chap. xv, "Open-Air and Open-Window Schools."

XXXIII. TRANSFER OF MATERIALS IN PLANTS

In anticipation of this study, place various kinds of twigs (preferably willow twigs) in jars of water to form roots. Three weeks or longer may be required. Girdling some of the twigs will enable you to make clear the relation between the bark vessels (phloëm) and the transfer of elaborated food in the stem.

Have on hand microscopic preparations, especially of longitudinal sections of fibrovascular bundles. For the isolated bundles, use corn stalks or celery, either fresh or preserved in from 2 per cent to 3 per cent formalin. For explaining the exogenous type of structure and growth, get sections of various dicot or coniferous twigs, one inch or more in diameter.

To show the distribution through the wood vessels (xylem) of stem and leaves, place seedlings, stalks of celery, or small succulent plants with roots, in tumblers containing dyed water (a few drops of red ink added to the water will do).

In connection with the problem of the ascent of sap, recall the pull of the transpiration current and the demonstration of root pressure. If necessary, repeat. Get the idea of capillarity clear by means of glass tubes of various dimensions, including old thermometer tubes or the finest tubes you can get by drawing out a glass tube softened in a Bunsen flame. Place the tubes in pigmented water and compare the heights to which the fluid rises. Suggest the greater capillarity of the microscopic vessels in the plant.

In connection with the problem of the descent of sap, discuss thoroughly the behavior of girdled trees. Is the sap of the maple

obtained from the ascending or from the descending current? What is the evidence?

Study commercial fibers (chiefly bast, such as flax, hemp, jute), bark fibers, etc. Correlate with commercial geography.

References. For the teacher: COULTER, BARNES, and COWLES, Textbook of Botany, pp. 388–397, 678–696; DUGGAR, Plant Physiology, pp. 272–273, 278–279. For the pupils: ANDREWS, Practical Course, pp. 112–118; BERGEN and DAVIS, Principles, chap. viii; OSTERHOUT, Experiments, pp. 224–258.

XXXIV. THE BLOOD

Obtain blood from a butcher or from a slaughterhouse. Add a little formalin to prevent decomposition.

Demonstrate clotting and the formation of serum by allowing the blood to stand quietly in a covered battery jar or beaker.

Whip some blood in a battery jar with an egg-beater or a whisk of small twigs. The beating withdraws the fibrin from the blood as fast as it is formed. Allow some of this whipped blood to stand alongside the other; when the clot is formed in the first, the second still remains fluid.

Wash the corpuscles out of the clot with cold water; show its fibrous structure and its protein composition, using nitric acid followed (after washing) with ammonia.

Examine human blood under the microscope, placing a drop in a little salt solution.

Pass oxygen through defibrinated blood contained in a tumbler; pass carbon dioxid through another specimen. See pages 11–13 for the preparation of gases.

Compare the lymph to the ocean as the medium of primordial life.

Point out that certain types of bleeders suffer from the failure of the blood to form a clot, whereas in other cases the defect is in the texture of the capillaries.

References. BIGELOW, Applied Biology, pp. 53–55, 482–486; HOUGH and SEDGWICK, Human Mechanism, pp. 132–135; STILES, Human Physiology, chap. xvi.

XXXV. THE CIRCULATION OF THE BLOOD

Demonstrate the circulation of blood in the web of a frog's foot or in the tail of a tadpole. To keep the animal quiet while on the stage of the microscope, it may be chloroformed; but you must be careful not to expose it too long to the fumes of the anesthetic. Place the frog in a battery jar in which is suspended a wad of cotton containing the chloroform, and cover. The low power of the microscope is sufficient. Point out that the large pigment cells are not in the blood; these cells are often confusing.

Demonstrate the structure of a beef or calf heart; get good models if these are available.

Have students tabulate data as to the circulation and as to the changes that take place in the blood in various parts of its course.

Note the exception to the rule that "blood goes from arteries to capillaries and from capillaries to veins," — namely, the portal circulation.

References. HOUGH and SEDGWICK, Human Mechanism, pp. 136–149; STILES, Human Physiology, chaps. xvii, xviii.

XXXVI. HYGIENE OF THE CIRCULATORY SYSTEM

Have students find and count their pulses for a given time (as for one minute), and record. Have the class stand up and go through setting-up exercises, and then record the pulse again.

If a stethoscope is available, have them listen to their own heartbeats and to any particularly interesting cases, as of murmurs etc. Call attention to the evidence of danger in overtraining in athletics, — for example, the experience of naval cadets in after life.

Present a collection of antiseptics suitable for the treatment of wounds and scratches. Study bandages.

Demonstrate methods for stopping bleeding, including nosebleed. Demonstrate the use of the tourniquet. Study the use of astringents.

Have students tabulate the results of their study, — types of situations and treatment, appliances, etc.

Have students tabulate the factors that have an influence upon the condition of the blood, and the results of various derangements, — as food, bowel habits, breathing, rest and fatigue, stimulants and narcotics, and so on.

References. For the teacher: CANNON, Bodily Changes in Pain, Hunger, Fear, and Rage, chaps. iii, v, ix, x; HOUGH and SEDGWICK, Human Mechanism, pp. 149–161; LEE, Health and Disease, chap. v; STILES, Human Physiology, chap. xix.

XXXVII. THE BLOOD AS A LIVING TISSUE

Review white corpuscles in terms of the properties and behavior of naked protoplasm, emphasizing especially types of irritability. Have on hand specimens of antitoxin, vaccine for typhoid and smallpox, and other serum preparations. Culture tubes and swabs for diphtheria cultures should be seen and handled, and their use demonstrated.

The idea of a precipitate can be represented very easily: add some sulfate solution to a solution of barium chlorid.

The subject is usually very interesting to young people, and leads to many questions. The teacher should be prepared to answer some of these concretely and specifically, — as the dosage for antitoxin, the *unit*, and how it is determined; the use of serum methods in diagnosis and in the specific identification of animal or other organic material; the use of the opsonic index; the diseases against which vaccination has been successfully used; the arguments pro and con on compulsory vaccination; the phenomena of anaphylaxis; and so on.

Get examples of individual variations in natural immunity and racial variation. Experience of students with acquired immunity, whether the result of disease or of special treatment; data on the relation of temperature, fatigue, nutritive conditions, etc. to immunity.

The subject of heredity often obtrudes itself insistently and must be handled firmly. To differentiate between the inheritance of a disease and the inheritance of a natural susceptibility is not difficult if the specific relation between bacteria and disease has been first made clear. But when it is necessary to speak of a

possible infection of an infant within the body of the mother, many teachers balk and make trouble for themselves. Draw upon the local department of health and the hospitals for help.

References. BUCHANAN, Household Bacteriology; HOUGH and SEDGWICK, pp. 497–504. Special reports on the history of smallpox vaccination; on experience of the army with typhoid vaccination; on the work of Behring, Metchnikoff, etc.

XXXVIII. WASTES AND BY-PRODUCTS OF ORGANISMS

Review chemical changes, with special emphasis upon the formation of new substances. Cell metabolism involves the formation of new substances; some of these are indifferent (water), some are useful (proteins), and some (carbon dioxid, urea, various acids) are injurious, at least in excessive quantities.

Grow some young seedlings in a moist chamber or under wet paper, in contact with a polished piece of marble. The etching of the stone shows the action of some *acid*, but chemical studies fail to reveal any organic acid secreted by the roots. The carbon dioxid (respiration product) in the water is sufficient to dissolve the carbonate of lime. Guard against the teachings of some of the older books, which still point to the etching as indicating an adaptation for dissolving mineral matter. Some of the dissolved mineral may be absorbed by the roots, but the secretion is of the same character as our exhalation of carbon dioxid through the nose.

Compare the accumulation of insoluble materials in the tissues of plants with the deposit of starch etc. in tubers and other storage organs.

Microscopic demonstration of pigments; chloroplasts as well as sap pigment may be found in the corolla of the pansy.

Study museum specimens of tannin and its sources. Give a demonstration of tanning (as of white of egg) and of tannery products. Study specimens of other plant products, — essential oils, alkaloids, acids, etc. Correlate with commercial geography.

Microscopic demonstration of silica and raphides in plant cells: use scouring rush (*Equisetum*) for the former, and Indian turnip (*Arisæma*) for the latter.

Study the Paramecium again, with special attention to the contractile vacuole. Any other available protozoa would do as well.

Cut kidney of calf or sheep lengthwise to show gross structure. Show microscopic preparations of kidney for gland structure. Microscopic sections of the skin are usually not satisfactory for those unskilled in the use of the microscope. A better idea of skin structure is to be obtained from a good model.

References. Coulter, Barnes, and Cowles, Textbook of Botany, pp. 412–416, 620–626, 718–725; Hough and Sedgwick, Human Mechanism, pp. 177–186; Sargent, Plants and their Uses, chaps. iv, v; Stiles, Human Physiology, chap. xxiii.

XXXIX. HYGIENE OF EXCRETION

What are the local and state regulations regarding the provision of drinking water in shops, factories, etc.? What are the local usages in this respect, and as to public drinking fountains?

To what extent is there need for official regulation regarding the provision of adequate toilets and washing facilities in industrial and commercial establishments? public comfort stations?

What are the public bathing facilities? What are the tendencies as to home bathing?

How much water (and fluid with food) does each of us take in during the day?

Relation of physical exercise to circulation and excretion; why perspiration is healthful.

References. Fisher and Fisk, How to Live, chap. iv; Hough and Sedgwick, Human Mechanism, pp. 413–424; Lee, Health and Disease, chap. iv.

XL. EXCRETION AND FATIGUE — XLI. FATIGUE AND THE WORKER

Use a dynamometer from the gymnasium, or a spring scale from the physics department, to explain the principle of the ergograph. Have a number of students make records at the beginning of the day and again at the close; or get records of gymnasium performance, as "chinning," made at intervals involving work and rest.

Compare experiences with fatigue and endurance.

Have students make special reports on the introduction of "scientific management," or "standard motions," in local industrial or commercial establishments, or on readings upon the subject. Have special reports on the findings of the Health of Munitions Workers Commission.

Collect data on hours, variations in work, pauses, and overtime in local establishments. What are the local or general regulations in these matters? To what occupations do they apply? What occupations are explicitly exempted? Why this discrimination?

Get information on the distribution of accidents in industries during the day; during the week; during the year. Have students plot graphs and analyze on physiological grounds.

Compare also records of school tests made with a view to measuring the influence of accumulating fatigue upon attention etc.

Show how exercise of the large muscles helps to rest the sedentary worker by accelerating the blood flow and facilitating perspiration.

References. CANNON, Bodily Changes in Pain etc., chaps. vi–viii; GOLDMARK, Fatigue and Efficiency; HOUGH and SEDGWICK, Human Mechanism, chap. v, pp. 314–320; LEE, Health and Disease, chap. v. Bulletins and current reprints of the United States Public Health Service; Bulletins of the United States Bureau of Labor Statistics.

XLII. NERVES AND THE REACTIONS OF ORGANISMS

Demonstrate some of the common reflexes by the students themselves. The knee-jerk is interesting and amusing when introduced for the first time, and it gives food for thought. Feed live worms to frogs in the laboratory, or use a dangling bit of red worsted. Have students report experiences in fishing, or with wild birds, or with domestic animals. Refer to the coughing reflex, and to sneezing and vomiting. Have students report their own observations and examples. The gland reflex that is most familiar is that of the mouth watering, but the cold sweat is perhaps not altogether strange (although this is not the same kind of reflex as the others mentioned).

Have prepared microscopic slides showing nerve structure. It is hardly worth while to study the muscle under the microscope.

Under chloroform dissect out the long muscles of a frog's leg, with the associated nerve; stimulate with the electric current from two battery cells. Show contraction in response to the stimulation of the nerve and in response to the direct stimulation of the muscle itself.

The dependence of the muscle upon the nerve connections may be suggested, though not strictly demonstrated, by bending the middle finger forward until the tip is opposite the palm of the hand, as in Fig. 10. The nerve fibers connected with the muscles controlling the end segment are compressed and apparently inactive. The end joint may be moved about (by the other hand) and seems lifeless.

FIG. 10

Use a pithed frog or one in which the cord is severed back of the medulla, to demonstrate the persistence of useful reflexes independently of the higher centers. Refer also to the chicken that runs around after the head is cut off. Have students suggest other examples.

Recall the increase in pulse rate on taking exercise, as an example of a reflex that does not shunt any impulses into the brain cortex. The increased heart work is due to a series of reflexes involving chemical stimulation (the partial pressure of carbon dioxid in the blood) and muscular reactions, but no conscious sensation and no voluntary influence upon the heart muscles or upon the breathing mechanism.

Point out the fallacy of assuming that the reflexes, or the natural behavior, of organisms are necessarily adaptive. The feeding of nearly all animals depends upon reflexes, and the escape from enemies also involves reflexes. If the reflexes were perfect, the frog would catch every fly he tries to catch, and the fly would escape from every frog that tried to catch him; the victim (food) would be assured to the feeder, and the safety of the prey would

be equally assured, and the feeder would starve. Have pupils find illustrations of the principle that some reflexes are indifferent, that some are even injurious, and that none are perfect as adaptations.

References. For the pupils: HOLMES, Animal Biology, chap. xxiii; HOUGH and SEDGWICK, Human Mechanism, chaps. vii, xv. For the teacher: DONALDSON, Growth of the Brain; LOEB, Comparative Physiology of the Brain; STILES, Human Physiology, chaps. vii, vi, viii, ix; STILES, The Nervous System.

XLIII. TROPISMS AND THE BEGINNINGS OF SENSE

The idea of a general reaction is not so strange as it may at first appear. Recall that the child winks not only when something approaches the eye, but also when he hears a sudden, loud sound, or when he is startled. The flight of the bird may be initiated by many different stimuli; a worm contracts in response to many different stimuli; the ameba shrinks into a spherical mass in response to many different stimuli; and so on. Compare seeing stars when the head is struck. The students will no doubt bring further examples, once they get the idea.

Experiments on the senses are always interesting and may be devised in endless variety. Have the students work in pairs.

To get differences between various parts of the skin in respect to discrimination in touch, use compasses with the points close together and gradually opened apart, noting the smallest separation that can be distinguished as two points in the different parts of the skin tried, — as the back of the hand, the neck, tips of fingers, tip of tongue, wrists, face, etc.

For the hot and cold points, try series of points on the palm of the hand, guiding by the folds. Use bits of wire or nails about two inches long. Place nails in hot water (about 80 degrees C.) and some in cold water (about 5 degrees to 10 degrees C.). Change as soon as the temperature of the nail approaches that of the skin closely. Have the students try the hot and cold points on the cheeks.

For experiments with taste, use dilute solutions of salt, sugar, acetic acid (vinegar), and very dilute solutions of quinine or aloes.

With a glass rod drawn to a very fine, rounded point (and rinsed clean after each use), have the students find and chart the distribution of the various papillæ on the tongue.

For showing the relation of odors to flavor, have various substances (foods, spices, condiments) placed in the mouth of a blindfolded student, holding his nose to prevent the inhalation of vapors from the air or from the pharynx. Record the discriminations made, either by naming the substances recognized or by describing them.

Call attention to the danger of interpreting movements of organisms in terms of likes and dislikes in the absence of real knowledge about the emotions involved. Earlier natural philosophy of all peoples appears to take this form, and it is indeed difficult to think of energies except as attractions and repulsions; but we may learn to use these terms without implying what usually goes with them when applied to human conduct.

References. For the pupils: CLODD, The Childhood of the World, Part II; HOLMES, Studies in Animal Behavior, chaps. i–v; HOUGH and SEDGWICK, Human Mechanism, pp. 263–265. For the teacher: HOLMES, Evolution of Animal Intelligence, chaps. iii, iv; LOEB, Forced Movements; LOEB, The Organism as a Whole, chap. x; MORGAN, Evolution and Adaptation, chap. xi; WATSON, Behavior, chaps. i–iii.

XLIV. EYES AND LIGHT

It is not difficult to keep Euglena in the aquarium, and in sufficient quantities to show the collection of the organisms on the illuminated side and the reversal of the tropism on exposure to direct sunlight. The idea of reaction depending on physiological state should offer no serious difficulties. Compare the effect of seeing tempting food before a meal and after a meal. The mouth does not water so readily when one is replete. So, a tired boy is not aroused by temptations that would ordinarily lead him to great exertions; when one is ill, he wants none of the amusements that ordinarily appeal to him; and so on. The students can furnish abundant illustrations from their own experience. The point to keep clear is that the protoplasm can be modified in its conduct

by the presence or absence of various substances, by temperature, by light, and by other incident forces.

Hydra and frogs are also valuable for showing the light tropisms and the influence of intensity. Earthworm habits are known to many boys. Assign for special report the behavior of earthworms under varying intensity of illumination; and the behavior of various water animals, including fishes.

Compound eyes of insects or other arthropods should be examined; have also microscopic preparations of eye surface and eye section.

A good model of the human eye is almost essential for a satisfactory study of this topic, but good charts may be acceptable substitutes. A box camera that is readily taken apart will be of help; get one that has a focusing screen of ground glass. Have the students study the pupil reflex with changing illumination, working in pairs. Rarely a person is found who can control the movement of the iris. It is probable that in most cases the control is indirect, — the subject produces the movements by changing the focus while appearing to be staring fixedly, or he does so by *imagining* sudden changes from extreme light to extreme dark, or the reverse. This is in a way similar to making the mouth water by *thinking* of good things to eat.

The students should finish this study with the conviction that many of the movements of organisms are quite as mechanical as those of a machine; and they should be as ready to give up attributing to emotions the movements of animals as they would be to deny emotion to a phonograph reproducing sentimental ballads. In the case of the animals, as in that of the phonograph, the phenomena, including the emotions, are produced because the thing is built thus and so.

References. For the pupils: HOUGH and SEDGWICK, Human Mechanism, pp. 244–258. For the teacher: HOLMES, Evolution of Animal Intelligence, chap. vii; STILES, Human Physiology, chap. xi; WATSON, Behavior, chap. xi. For reversal of tropisms: LOEB, Forced Movements, chaps. v–xi, xii, xix.

XLV. HYGIENE OF THE EYES

Where students' eyes are not regularly examined, arrange for examination with Snellen's test cards and with astigmatism charts.

Make clear the fact that *glare* depends not upon the intensity of the high lights but upon the *contrasts*. Have students collect information about light conditions in local establishments, with reference to abundance and distribution of illumination, presence of flicker, glare, etc. Have students collect information about special dangers to eyes in local establishments, and about methods of guarding the eyes. Make a study of goggles used for special purposes.

What are the local and state regulations concerning conditions inimical to people's eyes? Are there any local regulations requiring the administration of silver nitrate to the eyes of the newborn? Give statistical data as to the prevalence, increase, or decrease of blindness; preventive and remedial measures.

Demonstrate the administration of eye-drops and the use of the eye-cup. Show how a foreign body is to be removed.

Demonstrate the proper and improper placing of reading, writing, and other work in relation to illumination. Point out the objection to illumination of work by direct sunshine.

References. For the pupils: HOUGH and SEDGWICK, Human Mechanism, pp. 395–401; LEE, Health and Disease, chap. vii. For the teacher: PYLE, Personal Hygiene, pp. 169–274.

XLVI. SOUND SENSATIONS

Have some students report on the methods used by physicists for determining the vibration rates for light and sound waves. Come to a common-sense conclusion as to the old paradox about there being no sound if there were no ears.

Some experiments may be made on pitch discrimination; and you may find one or two students who can recognize absolute pitch.

Museum and demonstration specimens for various types of sound-perceiving organs. Note the lateral line in fishes, the eardrum in the cricket and locust, and so on.

Good models are essential for the study of ear structure, but good charts are helpful. It is not worth while, however, with most classes, to give much time to the detailed study of structure.

References. For the pupils: HOUGH and SEDGWICK, Human Mechanism, pp. 258–262, 401–402; STILES, Human Physiology, pp. 143–148. For the teacher: WATSON, Behavior, chaps. xii, xiii.

XLVII. RESPONSES TO GRAVITY

Have students report on insects and other animals in which they may have had an opportunity to observe evidence of response to gravity, including balancing and righting movements.

Demonstrate the idea of the statolith with a covered stender dish containing a cork. Show with blindfolded students that we are aware of our posture without seeing our environment.

With the frog it is easy to demonstrate compensatory movements. Place the live frog in a glass jar. Tilt the jar so as to bring the animal's snout down, and reverse. Tilt laterally. Turn on vertical axis. If the movements are properly timed, the responses of the animal are immediate and striking. It is possible to show that these movements are due to semicircular canal reflexes by eliminating the function of the eyes, either by covering them with an opaque mixture of cotton, vaseline, and lampblack, or by cutting the optic nerves, or by surrounding the jar with a large piece of paper or cloth that offers no point for fixation. On the other hand, it may be shown that many of these responses arise from eye reflexes, by destroying the semicircular canals or by cutting the nerves leading from them. In that case, however, there remain disturbances in locomotion, showing that the animal depends upon the semicircular canals for its orientation in space.

Have students make comparative tests of sensitiveness of hearing by determining the distances at which each may distinguish the ticking of a watch. The same watch will of course be used in all the tests.

References. For the pupils: HOUGH and SEDGWICK, Human Mechanism, pp. 262–263. For the teacher: WATSON, Behavior, chap. xiv. There will be numerous reports and monographs on the testing of candidates for aërial service, giving results of investigations conducted during the war.

XLVIII. INSTINCTS

Have students note examples of instincts in animals and in young children of their acquaintance, and then attempt to analyze these instincts, so far as possible, in terms of reflex chains.

Note that instincts, like reflexes, cannot be perfect in the adaptive sense.

Have students make note of variations in the manifestations of instincts brought about by changes in the physiological state or by the concurrence of two or more stimuli leading to more or less conflict between responses.

Have students report experiences with animals, or from their own past, in which instincts were modified, either through the elimination of elements or through the formation of associations. All sorts of learning and unlearning, breaking and training, in animals and in very young children would furnish illustrations.

References. For the pupils: DARWIN, Expression of the Emotions; DARWIN, Vegetable Mold and Earthworms; FABRE, The Wonders of Instinct; HOLMES, Studies in Animal Behavior, chaps. vi, xi. For the teacher: HOLMES, Evolution of Animal Intelligence, chaps. v, vi; LOEB, Forced Movements, chap. xviii; LOEB, Comparative Physiology of the Brain; LOEB, The Organism as a Whole; WATSON, Behavior, chaps. iv–v.

XLIX. HABIT

The study of habit should culminate in effective resolution. It is well to have clearly in mind the mechanism of habit formation, — the association factor and the short-circuiting of impulses out of the cortex into the spinal cord; but the important thing eventually is the habit of habit-control.

Have students give striking examples of habit responses (often humorous) and of good and bad habits. Reports on experience in training lower animals; on forming and breaking habits purposefully, — from observations as well as from personal experience, from fiction and drama, and from history and biography or other casual reading.

Get examples of inhibitions from students' experience and observation.

Study the relation of practice to habit formation and the measurement of practice effects, — for example, the number of repetitions or the time required for mastering a movement (in athletics, in workmanship, in musical performance, etc.); the memorizing of poetry or lines in a play; the mastery of mathematical processes, penmanship, drawing, and so on. Examples of arbitrary associations or habits are found in learning the telegraph instrument and codes, in stenography, in typewriting, in cipher codes, and so on.

Have students note examples of routineers among young persons, and of older people who are *not* routineers. Give examples of routine that could be replaced by other equally serviceable routine for the sake of gratuitous practice in changing habits, as shifting keys or money to another pocket, rearranging furniture at home, changing route to school, and so on.

Consider the utility and the dangers of habits.

References. JAMES, Psychology (Briefer Course), chap. x; HOLMES, Studies in Animal Behavior, chaps. vii–ix; HOUGH and SEDGWICK, Human Mechanism, chap. xviii; STILES, Human Physiology, chap. xii. For the teacher: HOLMES, Evolution of Animal Intelligence, chap. vii; LOEB, Forced Movements, chap. xix; WATSON, Behavior, chaps. vi–ix.

L. CHEMICAL INJURY TO THE NERVOUS SYSTEM

Have students report on the present status of regulatory laws pertaining to the manufacture, sale, advertising, and labeling of preparations containing alcohol and other habit-forming substances. A comparison of labels from patent medicines, headache cures, etc. is instructive. Have individual reports on special reading assignments.

The subject of this chapter should not be dismissed without attention being called to the advantages that the race has derived from an understanding of the physiological effects of various alkaloids and synthetic compounds. A report on the contributions of anesthetics and alkaloids to surgery etc. is quite as important as one on the dangers of these substances.

References. HOUGH and SEDGWICK, Human Mechanism, pp. 376–377; LEE, Health and Disease, pp. 128–132. In encyclopedias, articles on anesthetics.

LI. UNITY OF LIFE

This study should consist of a synthesis of all significant physiological ideas. Have students make lists of *all* the processes or activities that are common to several different organisms specified, the organisms selected representing diverse types and including plants as well as animals.

For each process or activity, have students describe the behavior of the organism as a whole, and also the behavior of single cells of the organism.

For each process or activity, have students compare the types of organisms selected; that is, point out similarities and differences.

For the organism as a whole, show the interdependence and coördination of processes; no part has meaning except in its relations to all the others.

References. For the teacher: CANNON, Bodily Changes, chap. xiv; CRILE, Man an Adaptive Mechanism; LOEB, The Organism as a Whole, chaps. i, xii; MORGAN, Evolution and Adaptation, chaps. i, iii, x.

PART III. THE CONTINUITY OF LIFE

LII. GROWTH AND REGENERATION

The idea of the varying ratio of surface and volume can be made clear to many students by means of suitable diagrams; but there are very many who find it extremely difficult, or even impossible, to think in three dimensions from data supplied by figures in one plane; that is, figures of two dimensions. These can be helped by the use of modeling clay. The clay is first cut into cubes of the same size, — say one inch or one centimeter. The cubes are stacked up into a larger mass, and the superficial area determined. The mass is successively broken down, with the resulting increase in exposed surface made obvious. One-inch cubes of wood may be used.

While the idea of the mathematical limits to the growth of a cell should be clear, it should not be emphasized to the point of excluding the idea of other factors operating in the limitation of growth. Current studies on the relations of internal secretions to the regulation of growth and form are constantly throwing new light on the subject.

Have regenerated leaves, starfish and Crustacea with regenerated limbs, specimens of knit chicken bones, etc. on hand for demonstration. In some of the larger cities it is possible to obtain from research laboratories or from museums specimens illustrating regeneration in vertebrates, mollusks, and other forms.

Have students look out for examples of pollarded and grafted trees, and for newspaper accounts of skin and bone grafting, or transplantations of organs. Have specimens of grafts for demonstration.

References. For the pupils: BERGEN and CALDWELL, Practical Botany, pp. 82–89; BERGEN and DAVIS, Principles of Botany, pp. 64–70; COULTER, BARNES, and COWLES, Textbook of Botany, pp. 417–426; DUGGAR, Plant Physiology, chap. xiii. For the teacher: DAVENPORT, Principles of Breeding, pp. 316–338; LOEB, The Organism as a Whole, chap. vii; MORGAN, Experimental Zoölogy, chaps. xv–xxii.

LIII. DEVELOPMENT

In the spring it is possible to have live frogs' eggs in dishes, and to watch their development under the microscope and magnifying glasses.

A series of models showing the development of *Amphioxus* (fifteen to twenty stages) is helpful. In the absence of models, charts may be used.

Have preparations and models showing the development of different types of insects, a fish, a frog, a bird (chick), and a mammal (sheep or rabbit). Eggs and cocoons of various local insects, also mealworms and other insect larvæ, should be examined alive. If possible, the emergence of the animals from the resting stage (egg or pupa) should be observed in the classroom by the students. In some localities it should be possible to visit incubators or henneries, to see the chicks come out of the shell. Along the shore, shedder crabs and the molting of many animals may be observed. Caterpillars in the process of pupation may be studied in the laboratory. From spring to late summer (from April to September for most parts of the country) it is possible to get complete life histories of mosquitoes by exposing tumblers of water on warm evenings; the female mosquitoes will deposit their eggs, and the development may then be watched in the laboratory, under a reading glass. Cover the tumblers with cheesecloth, to prevent the escape of the adults.

Under favorable conditions the development of the frog and the early stages of fishes can be followed in the laboratory. If possible, excursions to fisheries and to field should be made for the study of the stages in animal development.

If goldfish are kept in the laboratory or stock-room, one can manage to get fresh segmentation stages late in the winter and in the early spring. The animals are fed up in the winter; at the beginning of the breeding season the fish are isolated in large battery jars, and then "stripped" into shallow glass vessels.

Incubators for bacteriological work with thermostats can be used for the incubation of hens' eggs (104° F.). You must make

sure that the eggs are fertilized; it is best to purchase from poultry specialists, and to examine them by holding up to light after three or four days.

References. Special reports on life histories of various insects and batrachians; MITCHELL, CHALMERS, The Childhood of Animals, chap. ii. For the teacher: CONKLIN, Heredity and Environment in the Development of Man, chap. i, pp. 179–187; DAVENPORT, Principles of Breeding, chap. vii, pp. 336–344; KELLICOTT, General Embryology, chaps. i, ii.

LIV. CONDITIONS FOR DEVELOPMENT

It is very difficult for most people to separate in their minds the facts of growth from the facts of development. Call attention to diversities in *size* among the members of the class; then have the students decide whether size is always and everywhere directly correlated with maturity; that is, whether growth (in size) has always been identical with or even parallel with development. Nevertheless, conditions that are unfavorable to growth are likely to be unfavorable to development; ordinarily growth furnishes the material basis for development.

For a comparison of different conditions, concentrations, etc., in relation to growth of yeast, use fermentation tubes (Fig. 11).

Instances of malnutrition reacting upon development are to be found in nearly every community. Malformations and monstrosities of various kinds are referred to in books and in current literature. Consider the effects of early neglect, of foot-binding, etc.

References. For the teacher: AYRES, Laggards in our Schools, chap. xi; DAVENPORT, Principles of Breeding, chap. ix; MANGOLD, Problems of Child Welfare, Part I, chap. iii and Part II, chap. i; MORGAN, Experimental Zoölogy, chaps. ii–iii. Publications of the United States Children's Bureau.

LV. NEW ORGANISMS

Show yeast cells under the microscope for the buds. Fresh material (in dilute molasses) is necessary. To show the spore formation, use preparations from an older culture; that is, one from which the food has been exhausted.

Have students make experiments on the distribution of mold and yeast spores. Thin slices of bread exposed under various conditions or in different localities (or directly inoculated with dust) and placed in moist chambers will serve as media for the molds. For moist chamber a tumbler inverted over a few thicknesses of wet filter-paper or blotter will do. For the yeasts, fruit juices or sirup diluted (a teaspoonful to the pint), or weak cider, exposed in test tubes, which are then closed with plugs of cotton.

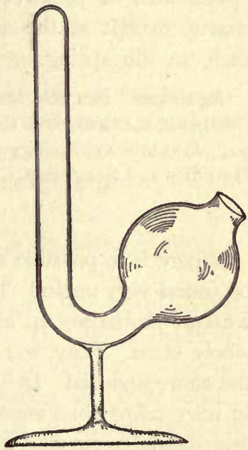

FIG. 11. Fermentation Tube

Fill the tube completely with the nutritive fluid. Insert the yeast or culture into the lowest part of the bend, using a pipette. Close the mouth with cotton. The accumulation of gas in the highest part of the tube is both an indication and a measure of fermentation. The bulb should be only partially filled, to leave space for the liquid displaced from the tube

Study spores of molds under the microscope. Mildews, rusts, mosses, ferns, and other plants should be drawn upon for specimens of spores. Many kinds of spores, including pollen grains, can be made to germinate by placing them in a drop of dilute sugar solution on a microscopic slide in a moist chamber. Germinate fern and moss spores on moist earth under glass. Sporangia should also be seen.

References. Special reports on spore formation etc. in various plants. HOLMES, Animal Biology, chap. xxvii; OSTERHOUT, Experiments with Plants, chap. ix. For the teacher: COULTER, BARNES, and COWLES, Textbook of Botany, pp. 805–816; PARKER and HASWELL, Zoölogy.

LVI. SEX

Favorable paramecium cultures show conjugation almost constantly; and if it is at all possible to manage it, the students should see the process under the microscope.

Conjugating spirogyra can be found late in the summer and in the fall, by collecting very early in the morning. Strings of ladders and zygotes can be preserved in formalin (2 per cent to 3 per cent) or mounted in glycerin for microscopic demonstrations.

Most of the colleges and experiment stations keep cultures of molds that will enable you to obtain zygote formation in the laboratory.

Gametes of rockweed and other algæ are best studied from charts, except at the seacoast, where fresh material is available early in the spring.

References. For the teacher: COULTER, Evolution of Sex in Plants; COULTER, BARNES, and COWLES, Textbook of Botany, pp. 816–824, 878–904; GALLOWAY, Biology of Sex; GEDDES and THOMSON, Sex; MORGAN, Heredity and Sex, chap. i.

LVII. FLOWERS

Where it is possible to have tulips for the first flower, they will be found very useful. Two students can easily work on one flower without mutilating it, and only a few need to be dissected for a whole class. They will keep so that successive classes may use the same material. In many cases it would be no more expensive to have tulips than some other flowers. Whatever flower is taken first should be regular, symmetrical, and perfect. Later other forms may be profitably studied. Flower models are helpful in class discussions, demonstrations, and recitations, as well as for comparisons of types that blossom at different seasons of the year. There should also be available an abundance of charts.

For pollen-tube demonstration, put pollen of various flowers in drops of dilute sugar solution on microscope slides; keep in moist chamber overnight; examine with microscope under cover glass.

Slices of larger ovaries may be mounted on glass slides and examined with magnifying glasses; if they are to be kept for some time, place in glycerin.

Fertilization in flowers can best be explained with the help of a blackboard diagram that is built up and changed with the progress of the description.

References. ANDREWS, Practical Course, pp. 196–223; BERGEN and CALDWELL, Practical Botany, pp. 20–23; BERGEN and DAVIS, Principles of Botany, chap. xiii, pp. 138–145; COULTER, Plant Life and Plant Uses, pp. 258–301; OSTERHOUT, Experiments, chap. vi. For the teacher: COULTER, BARNES, and COWLES, Textbook, pp. 825–834.

LVIII. POLLENATION — LIX. ADAPTATIONS OF FLOWERS

Flowers may be brought to the laboratory for examination as to the mechanism of pollen discharge. Get flowers of grasses, willows, oaks, poplars, maples, etc., as well as those with conspicuous corollas. The structure of the bumblebees, honeybees, and other pollenating insects should be studied in this connection.

Field trips for the study of insect visits to flowers are most interesting and valuable. Have the students find the pollen carriers for some of the common wild and cultivated plants. What insects visit more than one kind of flower? What flowers are visited by more than one kind of insect? Are the visits of mutual advantage in all cases?

Have students find out what evidence there is that the wind brings pollen over a considerable distance. In regions cultivating pedigreed grains and corn, farmers often have to construct windbreaks to prevent foreign pollen from crossing with their special varieties. Hybrid willows and other species of wind-pollenated trees are evidence of such crossing.

Study two or three species of zygomorphic flowers that are dependent upon insects, and one or two that are self-pollenating. Visit gardens and greenhouses.

Assign special readings and reports on extrafloral nectaries, on specific insect-flower relations, on economic aspects of the relation, and on cleistogamous flowers.

References. ANDREWS, Practical Course, pp. 235–249; BERGEN and DAVIS, Principles, chap. xxxii; COULTER, Plant Life, pp. 301–324; DARWIN, Forms of Flowers. For the teacher: COULTER, BARNES, and COWLES, Textbook, pp. 834–878; MORGAN, Evolution and Adaptation, chap. i.

LX. FRUIT AND SEED DISTRIBUTION

Dried fruits of many different species are easily kept in boxes and may be used over and over again, although the collection should be constantly supplemented and enlarged by new additions. Present materials in ecological relations; that is, in accordance with the agency of distribution or the type of seed protection.

Field studies along roadsides, vacant lots, and the woods will furnish abundant illustrative material and opportunity for collecting.

References. ANDREWS, Practical Course, chap. viii; BERGEN and DAVIS, Principles, chaps. xvi, xxxiii; COULTER, Plant Life, chap. viii; OSTERHOUT, Experiments, chap. vii; Farmers' Bulletins. For the teacher: COULTER, BARNES, and COWLES, pp. 904–929.

LXI. ALTERNATION OF GENERATIONS

Use fresh or dried moss plants (the pigeon-wheat moss, *Polytrichum*, is good and found almost everywhere) showing both gametophytes and sporophytes. Students should see archegonia and antheridia through the microscope, but good blackboard drawings or charts are necessary for satisfactory study.

Fern prothalli can be grown by sprinkling the spores on moist earth placed in dishes, covered with glass and kept at room temperature. Show archegonia and antheridia through microscope.

Hydromedusæ are best studied in small vials with the magnifying glasses. Thus preserved, the specimens will keep indefinitely.

References. BERGEN and DAVIS, Principles, chaps. xxiv–xxix; COULTER, Plant Life, pp. 401–403. For the teacher: COULTER, Evolution of Sex in Plants; COULTER, BARNES, and COWLES, pp. 92, 264–268, 805–824.

LXII. REPRODUCTION IN ANIMALS

This subject does not lend itself readily to laboratory or field study by young people; nor is it always feasible to discuss it in class, especially in mixed schools.

Where it is not feasible to keep live fish (see p. 69), it may be possible to arrange for visits to an aquarium or to a fish station, where the students may see roe and milt, and where they may see a demonstration of "stripping" and artificial fertilization.

There is a great deal of interesting reading on the breeding habits of common animals, to which students should be referred, even if there is no class discussion of results.

References. Special reports on habits of birds, fishes, and other animal groups.

LXIII. INFANCY AND PARENTAL CARE

This is a review study of the whole subject of reproduction, with emphasis upon the relation between parent and offspring, and of the two to the species. This may be correlated with historical and ethnological studies, as well as with social science and community civics. Have students prepare diagrams showing the increasing dependence of spores, gametes, and zygotes upon the parent, in series of plants or of animals. Charts giving a general view of the plant and animal systems are helpful in this connection, even if no attempt has as yet been made to study classification. See Chapters LXXXVI and LXXXVII of the text.

Guard against the interpretation of phenomena in terms of "purpose."

References. MITCHELL, The Childhood of Animals, especially chaps. i, iii, iv; PYCRAFT, The Infancy of Animals; BURBANK, Training of the Human Plant; FISKE, The Prolongation of Youth.

PART IV. ORGANISMS IN THEIR EXTERNAL RELATIONS

LXIV. OBSTACLES TO LIFE

Earlier experiments have already demonstrated the influence of external forces upon growth and upon development. This chapter is in the nature of a summary with a view to a new departure.

Have students make (in the form of a table) a list of ten familiar plants and ten familiar animals, with a note on the characteristic appearance or behavior (*a*) at high temperatures (summer) and (*b*) at low temperatures (winter).

Have students state experiences with frostbite, frozen ear, etc., with frozen snakes or fish, and so on. Why is freezing of protoplasm reversible, whereas the effect of heat is irreversible? What are the dangers of natural ice? What is the object of cooling milk immediately after taking it from the cow? What is the object of keeping milk and other food at low temperatures? What is the use of pasteurizing milk, and how is it accomplished? What is the objection to boiling milk?

In discussing the effect of water shortage or excess, point out that some of the characteristic summer and winter conditions of plants and animals are due to the water relation. What practical use is made of the fact that protoplasm cannot be active without water? What practical methods are employed for excluding water from materials that might otherwise be destroyed by bacteria, molds, or yeast?

If the influence of light upon growth has not been demonstrated earlier, it should now be shown with bacteria cultures in petri dishes. Cover a portion of each dish with black paper; or cover the whole dish and cut distinctive holes or letters in the paper, to admit light. After exposing the sterilized medium to infection, the covers are put on and the dishes are exposed to strong sunlight

at room temperature or warmer; later they are examined for bacterial growth, showing different behavior in light and darkness.

What practical use can be made of the fact that light is injurious to protoplasm (as in bacteria)? Refer to the use of ultraviolet rays for the sterilization of water supplies and other food materials. Have students make special reports.

What practical use is made of the fact that many salts (chemicals) are injurious to living things? Refer to the use of salt or ashes on the ground for killing weeds. In the use of salt (and sugar) for preserving food, part of the effect is no doubt due to the *drying*. Compare the drought characteristics of many swamp plants, such as the mangrove.

References. For the pupils: COULTER, BARNES, and COWLES, Textbook of Botany, pp. 565–589, 704–718; DARWIN, Origin of Species, chap. iii; JORDAN and KELLOGG, Evolution and Animal Life, chap. iii. For the teacher: MORGAN, Experimental Zoölogy, chap. ii.

LXV. THE CONFLICT OF LIFE WITH LIFE

Most of the ideas in this chapter deal with abstractions that cannot be illustrated or demonstrated directly, — as predation, parasitism, competition, or struggle. But these ideas can be easily formed from familiar examples.

Have specimens of tapeworm and microscopic preparations and pictures of roundworm, hookworm, and other parasites.

Students can suggest many examples of predatory and parasitic relations, and comprehensive lists can be compiled from their reports.

Selective and nonselective elimination should offer no difficulty; examples abound on every side, in human affairs as well as in those of the common animals and plants. The important thing is to make clear the metaphorical sense in which the word *struggle* is used, and to form connotations that avoid the banal element of competition.

References. BERGEN and CALDWELL, Practical Botany, chap. xxi; BERGEN and DAVIS, Principles, chap. xxx; DARWIN, Origin, chap. iv; EALAND, Insects and Man, chap. vii; HODGE and DAWSON, Civic Biology, chaps. xviii, xx, xxiv; JORDAN and KELLOGG, Evolution and Animal Life, chaps. v, xvii. For the teacher: MORGAN, Evolution and Adaptation, chaps. iv, v; MORGAN, Experimental Zoölogy, chap. xiii.

LXVI. PROTECTIVE ARMORS OF ORGANISMS

It is not worth while to study skin structures of plants and animals in detail. Illustrative specimens should be on hand, and visits to museums, gardens, menageries, aquaria, etc. encouraged. The general ideas discussed are simple enough and should not take too much time beyond the reading and summarizing in notebooks, with perhaps additional examples.

References. BERGEN and DAVIS, Principles, chap. xxxi; COULTER, BARNES, and COWLES, Textbook, pp. 741–744.

LXVII. PROTECTIVE PIGMENTS AND APPEARANCES

That colors, patterns, etc. may protect is obvious enough. More difficult, and perhaps more important, is the idea that the resemblances etc. may be quite fortuitous and without practical significance either in the lives of the organisms or in the evolution of species. Have prepared specimens to illustrate protective coloration, warning coloration, and mimicry; have museum studies and encourage students to bring in specimens found afield.

What experiences have the students had with sunburn and tan? Refer to Cunningham's experiment with flatfish.

What experiences have the students had with the behavior of animals that show dependence upon the coloration etc.?

Have cactus and other xerophytic plants to illustrate reduction of surface as an adaptation. Get some students to experiment on whether the drought brings about the reduction of surface, as a modification during development, or whether these plants are incapable of living where there is a relative excess of water.

References. For the pupils: DAVENPORT, Elements of Zoölogy, pp. 35–38; JORDAN and KELLOGG, Evolution and Animal Life, chap. xix; KELLOGG, American Insects, chap. xvii; POULTON, The Colors of Animals; WALLACE, Natural Selection and Tropical Nature, chap. v. For the teacher: MORGAN, Evolution and Adaptation, pp. 357–360.

LXVIII. PROTECTIVE MOVEMENTS — LXIX. PROTECTIVE ACTIVITIES

Have students handle live animals of various kinds, in the aquarium and in the vivarium at school or wherever they can outside, and report the contracting and flight movements. Many of these movements are already familiar enough, and too much time should not be taken for their consideration in the classroom. "Playing possum" is a widespread reaction; point out that it is a general reaction that may or may not be useful, and that may or may not be related to the advantage of the species.

Have specimens of fence lizards and other chameleons, and note color changes in other reptiles, in batrachians, and in fishes.

Where there is opportunity the students that take an interest in morphology may be encouraged to study homologies and analogies in animal appendages. Individual students might prepare mounted series of crustacean or insect appendages and mouth-parts.

Special reports on bird and fish migrations should include results of field observations as well as of reading.

Laboratory and field studies of burrowing worms and insect larvæ, and of birds' nests.

Charts and microscopic demonstration of nettling cells.

Study of leaf-scars to show self-healing surface; microscopic preparation of the scission layer.

Encourage students to collect insect galls and to find out what insects cause them on common plants.

Have special reports made on field observations and readings on the homing habits of animals, from the point of view of protection.

References. COULTER, J. G., Plant Life and Plant Uses, pp. 242–247; COULTER, BARNES, and COWLES, Textbook, pp. 354, 582–588; OSTERHOUT, Experiments, pp. 212–215, 332. For the teacher: MORGAN, Experimental Zoölogy, chap. xvi.

LXX. THE FOREST IN RELATION TO MAN

The forest has for a long time been the favorite hook upon which to hang the sermon of conservation, since it lends itself admirably to the purpose, both for economic reasons and for biological ones.

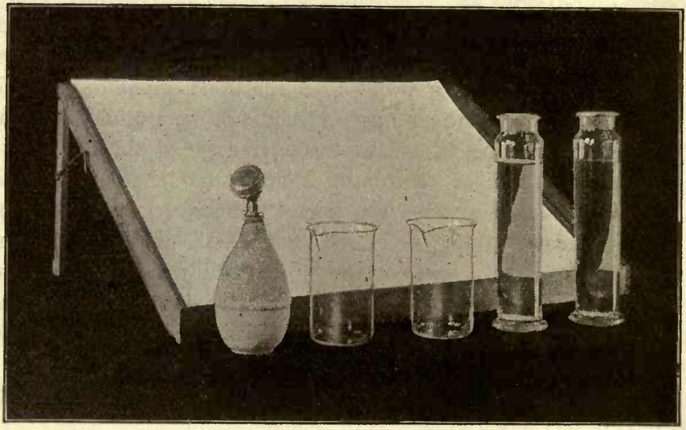

FIG. 12

The slope consists of a wooden frame, supported at an angle of about 45 degrees, inclosing a pane of glass with a trough at the bottom leading to a small drain-hole at the end. The most convenient size is that of the large blotters used on desks or in desk pads. Two beakers, two cylinders, preferably graduated, a florist's spray, and a supply of water complete the equipment. Equal quantities of water are placed in the cylinders or graduates. The water from one of these is drawn into the bulb of the spray and rained first upon the bare glass, representing a deforested mountain side, and then upon the slope covered with two blotters, one representing the forest trees and the other representing the forest floor, or duff. In each case as much water as possible is collected in the beaker and returned to the respective cylinders for comparison. The water can be seen across the schoolroom more easily if it is slightly colored, as with a few drops of red ink. (Apparatus designed for use in the Department of Public Education of the American Museum of Natural History by George H. Sherwood, Curator)

This subject is perhaps best studied in connection with Arbor Day observance. Special reports on various aspects of the forest in relation to human welfare furnish the best means of arousing interest and impressing the students with the far-reaching contacts

between the forest and human affairs. These reports may take the form of statistical reports on such topics as the quantities or values of various forest products; water supply, navigation, water power; soil erosion; harbor maintenance; value of improved lumbering methods; injurious species of insects and fungi, and specific methods of control; the birds in relation to the forest; danger of fire and the prevention of fire; relative values of different kinds of wood; different rates of growth; methods of reforesting; special services of state and federal bureaus; recent legislation; etc.

The effect of clearing upon soil erosion, floods, etc. is often demonstrated by means of the model illustrated in Fig. 12. This demonstration does not, of course, *prove* that the forest retains water longer than does the nude soil; it only helps to visualize the relationships between the two kinds of hillside and the run-off.

References. BERGEN and CALDWELL, Practical Botany, chap. xxii; COULTER, J. G., Plant Life, pp. 195–200; HODGE and DAWSON, Civic Biology, chap. vi; MOON, The Book of Forestry; ROGERS, The Tree Book. Yearbooks of the United States Department of Agriculture; reports and bulletins of the United States bureau of Forestry; bulletins and reports of state departments of agriculture; United States Department of State, publications on forest reserves and recreation.

LXXI. BACTERIA AND HEALTH — LXXII. CONTROL AND USE OF BACTERIA

The subject matter here is largely in the nature of a new synthesis of material that is for the most part already familiar.

The destruction of bacteria discharged from diseased persons, and the prevention of infections, are the practical problems suggested. Various methods, materials, and regulations directed to these ends should be correlated with the data given in the table on page 387. Have specimens of the germicides to be used in various situations; and perhaps make comparative studies of their effectiveness with petri-dish cultures. An interesting experiment in connection with this study is to obtain cultures from a mouth-rinsing thrown into a petri dish, and then a similar rinsing after the use of a commercial mouth wash.

Special reports on methods and regulations in hospitals and sickrooms are interesting and valuable.

Typhoid carriers are presented to the public attention from time to time; local and current references are more interesting than remote cases.

Special studies may be made of local conditions and current activities in the way of legislation and administrative regulation, with reference to the various items mentioned in the latter part of Chapter LXXI and in section 434 of Chapter LXXII, and with reference to markets, cold-storage plants, etc.

Analyze city or state health department reports of morbidity and mortality.

For the economic aspects, reports upon accessible industries mentioned in the text, or other local activities in which microörganisms play a part, and the collection of commercial products or specimens illustrating processes, should be encouraged. Have demonstrations of such specimens in class, and, in some cases, of actual processes, as the souring of vinegar and the rotting of flax or of sponges.

References. Buchanan, Household Bacteriology; Conn, Agricultural Bacteriology; Hodge and Dawson, Civic Biology, chaps. xxi–xxiii; Holmes, Animal Biology, chap. xxxvi; Jordan, Textbook of General Bacteriology, chap. xxxiv; Lipman, Bacteria in Relation to Country Life, chaps. i, xxxvi–xlix; Locy, Biology and its Makers, chap. xiii. Bulletins and reports of the local and state departments of health and of the United States Public Health Service. For the teacher: Chapin, Sources and Modes of Infection; Jordan, Textbook of General Bacteriology, chaps. i, v, xxii, xxxiv.

LXXIII. INSECTS AS SPREADERS OF DISEASE

Prepare a number of petri dishes with nutrient agar or gelatin. Have students bring in flies caught in various parts of town and in various situations. Place a fly in each dish, after clipping off the wings, and keep in a warm place for two or three days. Do not omit several control dishes. Have students summarize results in tabular form.

Have surveys made of various parts of town accessible to the students, to find out the relative prevalence of flies (especially in

relation to food markets) and the distribution of breeding places. Where the flies have not been virtually exterminated through the efforts of the community, it is legitimate to undertake a systematic campaign, in coöperation with official bodies and civic organizations. Where the fly is no longer a pest, this study has only a historical interest; but the history is so recent that it is worth impressing as an example of man's control of his environment.

References. CHAPIN, Sources and Modes of Infection, pp. 417–447; EALAND, Insects and Man, pp. 119–136; HODGE and DAWSON, Civic Biology, chap. x; KELLOGG and DOANE, Economic Zoölogy, pp. 377–384; KELLOGG and DOANE, Insects and Disease; RILEY and JOHANNSEN, Handbook of Medical Entomology, chap. v. Bulletins and reports of local and state departments of health; bulletins of the United States Public Health Service and of the United States Department of Agriculture.

LXXIV. INSECTS AS INTERMEDIATE HOSTS

Get first a quantitative idea of the prevalence of malaria (or yellow fever!) in the locality. Students should set out to find possible breeding places for mosquitoes, and chart their distribution. Study local operations directed toward the extermination of mosquitoes.

Have special reports on the sanitary work in the Canal Zone and in Cuba.

Have special reports on sanitary work in the nearest harbors.

Draw diagrams illustrating the idea of alternate hosts. Have special reports on the extermination of parasites through attacks upon intermediate hosts.

References. CHAPIN, Sources and Modes of Infection, pp. 380–417; EALAND, Insects and Man, pp. 88–119, 136–159, chap. iv; HODGE and DAWSON, Civic Biology, chap. xi; JORDAN, Textbook of General Biology, chap. xxx; KELLOGG and DOANE, Economic Zoölogy, pp. 367–377.

LXXV. INSECTS AND HUMAN WEALTH

Collect specimens of useful and destructive insects, including the various stages wherever possible; specimens of commercial products and of stages in industrial processes; specimens of spoiled materials; insecticides.

Have special reports on life histories, injuries, and means of fighting destructive insects, and on life histories, value, and means of cultivating useful insects. Study the statistical data. Give special attention to economic insects of local or current interest.

References. EALAND, Insects and Man, chap. v; HODGE and DAWSON, Civic Biology, chap. xii; KELLOGG, Insect Stories; KELLOGG and DOANE, Economic Zoölogy, chap. xvii. Bulletins and reports of state and United States departments of agriculture; farmers' bulletins and yearbooks, United States Department of Biology.

LXXVI. INSECTS AND OTHER ORGANISMS

Collect specimens of insects injurious to useful plants (complete life histories if possible), together with specimens of the plants in question. Species of local or current interest should receive special attention. Have special reports on life histories, extent of damage, and means of control.

Make a similar study of insects related to economic animals.

Wherever possible, students should be encouraged to mount specimens of economic insects in arrangements showing their relations, — for example, a twig with scales and lady-beetle, or life history of gypsy moth, life history of calosoma, and twig of host plant.

Have special reports on state and federal activities in the cultivation of insects for the destruction of injurious insects.

Have reports on spraying and other methods of control; study a spraying calendar etc.

New examples of the interrelations of species should be recorded; study the fate of introduced species of plants and animals, and the effects of introduced species upon native species.

References. EALAND, Insects and Man, chaps. ii, viii; HODGE and DAWSON, Civic Biology, chap. xiv; KELLOGG and DOANE, Economic Zoölogy, chaps. xxx–xxxvii. Bulletins of the United States Bureau of Entomology; state bulletins.

LXXVII. BIRDS IN RELATION TO MAN

Have field observations on resident and migrating birds. Encourage students to become acquainted with the identities and habits of birds, including distinctive songs, notes and calls, and food plants and animals. The "shooting" of birds with cameras, and their "capture" by means of suitable nesting boxes etc., offer worthy substitutes for the expression of primitive gaming instincts, and should be encouraged. Have special reports on life habits and economics of important birds, particularly such as are of local or current interest. Summaries of the various reports should be prepared in tabular form, and should include information about habitats, seasons, and food plants and animals.

References. BAYNES, Wild Bird Guests; BEEBE, The Bird; HODGE and DAWSON, Civic Biology, chaps. iv, v; HOLMES, Animal Biology, chap. xxi; JOB, Domestication of Wild Birds. Reports and farmers' bulletins, United States Department of Agriculture; annual summaries of game laws, United States Department of Agriculture; publications of the State Department of Agriculture; publications of the Audubon Society.

LXXVIII. SOCIAL LIFE OF ORGANISMS

Have specimens illustrating high points in the evolutionary series, both plant and animal; or provide suitable charts. The emphasis will be upon the differentiation that follows upon integration, and this should be compared with the parallel process observed in the course of development (Chapter LIII).

Access to a glass beehive or to an ants' nest under glass is desirable. Have special reports on division of labor in ant and bee colonies. The distinction between the automatic coördinations that obtain in such colonies and the conscious coöperation of various human enterprises should be made clear.

References. FABRE, Social Life in the Insect World; HODGE and DAWSON, Civic Biology, chap. xiii; HOLMES, Animal Biology, chap. vii; JORDAN and KELLOGG, Evolution and Animal Life, chap. xviii; KELLOGG, American Insects, pp. 490–561; KROPOTKIN, Mutual Aid; LUBBOCK, Ants, Wasps, and Bees; MAETERLINCK, The Bee; WHEELER, Ants, especially chap. xxiii.

PART V. HEREDITY AND EVOLUTION

LXXIX. VARIATION

For the study of variation, use any organic structures available in quantities. Leaves are to be obtained in all regions and are easily preserved for use in all seasons. Fingers of girls and boys, feathers of birds, claws or teeth of mammals, wings of insects, shells of mollusks, pulse beats, ray-flowers, and hundreds of other things are just as good.

Have a group of specimens matched as to form,—for example, maple leaves or finger prints.

Make a census of careful measurements. Distribute the material in small boxes, envelopes, or bottles, with rulers or scales divided to millimeters. Instruct students to *sort* the material into classes representing differences of one or two millimeters. A class of ordinary size can obtain several hundred measurements in a short time; have a committee of students compile the results. If several classes are doing parallel work, it is worth while to consolidate the data for all and illustrate the increased smoothness of the curve obtained from large numbers. Have results presented graphically as well as in tables. Have them posted on blackboard or chart, and if possible have a copy made for each student.

When the idea of variation is fairly clear, have students bring in examples of variations, physiological as well as meristic etc., that they have themselves observed among human beings and among other organisms. Have them suggest for each variation what the possible advantage or disadvantage of extremes may be to the organism. It is worth while, in connection with this study, to have pupils *record* their opinions or beliefs as to the causes of the variations observed; these views are to furnish a basis for further analysis, or hypotheses for further study, leading to a clearing up of the thought. Examples of modifications in which the causes are

obvious or inferred with some degree of probability should also be collected. Have noted the modifying effects of disease, exercise, or disuse, nutritional extremes, habit formation, mechanical injuries, injuries caused by insects or other animals, etc.

Have pictures and charts showing various breeds of domesticated animals and plants and different varieties of cultivated fruits, vegetables, and flowers; study seed catalogues, poultry catalogues, etc. Have special reports on new varieties of useful or fancy plants and animals, from the United States Department of Agriculture yearbooks, from reports of the nearest agricultural experiment station, from the State Department of Agriculture, from the reports of breeders' associations, etc. Have a special report on the work of Burbank.

References. BERGEN and CALDWELL, Practical Botany, pp. 417–421, 428–430; JORDAN and KELLOGG, Evolution and Animal Life, chaps. ii, ix. For the teacher: BATESON, Materials for the Study of Evolution; DAVENPORT, Principles of Breeding, chaps. i–v; MORGAN, Evolution and Adaptation, pp. 261–270; VERNON, Variation.

LXXX. HEREDITY

In having students bring in examples of family resemblances, consider mental traits that are not likely to be the results of habituation or common experience, as well as physical traits. Similarities in voice, pronounced likes or dislikes, the manner of folding the hands, various mannerisms, and physiological idiosyncrasies furnish interesting material for study and comparison. Uncles and cousins and aunts should be considered, as well as parents and grandparents.

The most valuable outcome of such studies should be a clear realization of the fact that the resemblance to the two houses is a resultant of many *complete* resemblances to one side and many complete resemblances to the other, rather than a blending of the several characters.

Have a special report on the alternative characters studied by Mendel. Have specimens and pictures of varieties of cultivated plants and animals, for study of alternative characters, students to find as many pairs as possible in a given set of individuals.

Use blackboard and colored crayons for developing the Mendelian principles. Use checkerboard diagram to show the segregation of two or more characters. Where possible, show identity of the segregation formula with the algebraic formula for the square of a binomial etc.

To make clear what is meant by chance in scientific discussions, refer to (or demonstrate in class, or assign for trial and report) the experience of drawing cards from a pack or of throwing a coin or dice. The *chances are even* that a card drawn at random will be black or red; that a coin will fall heads up or tails up. A second throw of a coin faces the same chances, and so the third and the millionth. But the chances that all in the series will fall the same way are very small; and the longer the series, the smaller the chances. It is possible for a coin to come heads up six times in succession; but it is more likely to come in some other succession, as there are a great many possible *others*. Yet, if we took any *one* of the others, the chances that that one would come up are just the same as the chances that the six heads would come up. Now the larger the number of throws, the greater the possible number of combinations, and the smaller the chances of any particular combination falling out. With three throws there are eight possible combinations (2^3), any one of which has one chance in eight of appearing; with four throws there are sixteen possible successions (2^4), and each has one chance in sixteen of appearing; with five throws there are thirty-two combinations; and so on, the chances for a special combination diminishing in geometrical ratio. When this idea is applied to the combination of alternative characters derived from the two ancestral lines, we can see that the chances of a particular combination of characters being duplicated are practically one in infinity.

References. For the pupils: CASTLE, Heredity in Relation to Evolution and Animal Breeding; DONCASTER, Heredity in the Light of Recent Research; GUYER, Being Well Born, chaps. i, iii, iv; HOLMES, Animal Biology, chap. xl; JORDAN and KELLOGG, Evolution and Animal Life, chap. x. For the teacher: LOCK, Variation, Heredity, and Evolution, chaps. vii, viii; MORGAN, Heredity and Sex; PEARSON, The Chances of Death; THOMSON, Heredity.

LXXXI. APPLICATIONS OF THE PRINCIPLES OF HEREDITY

Have special reports on the economic and esthetic contributions of plant and animal breeding, from recent bulletins and current publications. Have specimens (where possible) and pictures of new combinations brought about through the systematic application of known facts and principles. Assign readings on eugenics.

References. BAILEY, Plant Breeding; BERGEN and CALDWELL, Practical Botany, chap. xxiii; CASTLE, Heredity in Relation to Evolution and Animal Breeding; DAVENPORT, Principles of Breeding, chaps. xix, xx; GUYER, Being Well Born, chaps. v, vii, x; HARWOOD, New Creations in Plant Life. Yearbooks and bulletins of the United States Department of Agriculture; seedsmen's catalogues. For the teacher: CASTLE, COULTER, and others, Heredity and Eugenics; DAVENPORT, Heredity in Relation to Eugenics; GODDARD, The Kallikak Family.

LXXXII. HEREDITY AND PROTOPLASM

It should be clear that whatever is inherited is not physically passed on, — the red cow is just as red after the calf is born as she was before; and the fertilized egg of the leghorn has not white feathers, — it has no feathers at all, not even in miniature.

Get the idea of the immortality of the germ plasm by comparing with the immortality of protozoan protoplasm.

Show stained cells for karyokinesis. Show stained egg cells, as of *Ascaris*, for chromosomes and reduction. Explain the successive steps in reduction and maturation divisions with the help of blackboard diagrams.

Have students make special reports on sports among animals and plants.

Discussion of the transmission of modifications will probably arise without special stimulation from the teacher, — it always does if there is the slightest occasion. The question of prenatal influence and of the cause of birthmarks should also be given a chance if it presents itself.

References. CONKLIN, Heredity and Environment in the Development of Man, chap. ii; GUYER, Being Well Born, chap. ii; LOCK, Variation, Heredity, and Evolution, chap. x.

LXXXIII. EVOLUTION

Review the idea of universality of change, and emphasize the practical importance of understanding changes. Have students give examples of the use of knowledge to bring about desirable change, to avoid undesirable change, etc.

Have examples of continuously progressive changes and of cyclic changes. Does history repeat itself? Guard against the tendency to assume that we must pin our faith to a yes or a no answer to every question. There are perhaps other possibilities, and both types of change may exist side by side.

Show fossils peculiar to the region, and geographical varieties of plants and animals. Have museum studies of fossil series and of morphological series. Explain what a reconstruction is, its basis, and the degree of its validity. Present alternative theories or hypotheses to account for fossils.

Have special readings (with reports) on the various classes of evidence for descent with modification. It is important to avoid the tendency to confuse the *evidence for* evolution, considered as a purely historical *fact*, with speculations concerning the *mechanism of* evolution.

References. HOLMES, Animal Biology, chap. xxviii; JORDAN and KELLOGG, Evolution and Animal Life, chaps. iv–ix. For the teacher: LOCK, Variation, Heredity, and Evolution, chaps. i–iii, v; MORGAN, Critique of the Theory of Evolution, chap. i; MORGAN, Evolution and Adaptation, chaps. ii, iii.

LXXXIV. APPLICATIONS AND THEORIES OF EVOLUTION

The time given by high-school or college students to the study of evolution must justify itself not in a resulting familiarity with theories or with illustrations and statistics; it must justify itself in a resulting *attitude toward life.* It may well be that a portion of our population is constitutionally incapable of acquiring a dynamic outlook; but where there are no constitutional barriers, the failure to acquire this dynamic viewpoint must be charged to the school and specifically to the teachers of biology and history.

The study of this section may well take the form of a free discussion that will ferret out lingering doubts and prejudices, not for the purpose of inculcating sound doctrine on the subject of evolution, but for the purpose of getting the students to feel the majesty of the larger concepts. An academic analysis or a purely intellectual assent is not sufficient.

Have special reports and summaries on the views of Lamarck, Darwin, De Vries. Have reports on experimental work in evolution.

References. CONKLIN, Heredity and Environment, chap. v; GUYER, Being Well Born, chap. x; HARWOOD, New Creations in Plant Life. Yearbooks of the United States Department of Agriculture. For the teacher: KELLOGG, Darwinism To-day; LOCK, Variation, Heredity, and Evolution, chap. x; MORGAN, Evolution and Adaptation, chap. iv.

PART VI. MAN AND OTHER ORGANISMS

LXXXV. THE CLASSIFICATION OF ORGANISMS — LXXXVI. KINDS OF PLANTS — LXXXVII. KINDS OF ANIMALS

It is not to be expected that students will attain to a clear view of the plant and animal series from the study of a chapter or a chart. It is only through prolonged association with many forms, and through constant thought upon similarities and differences and relationships, that this is to be attained.

As a means of facilitating acquaintance with forms, present constantly new specimens to illustrate the biological principles studied. These new specimens come to the student as laboratory material for direct handling; as demonstration specimens; as exhibition material in the wall cases etc. of the classroom; as objects of observation in the field, in museums, in the flower or vegetable show, in the bird store, in the menagerie or at the circus, in pictures found in books and magazines and upon the classroom walls etc., in stereopticon and motion-picture views, and so on. Acquaintance with forms is the beginning; classification and naming come later.

But children begin to classify and name almost as soon as they begin to speak. Call attention to the way children name a new object in terms of the familiar one which it most resembles.

Discuss the difficulty of supplying enough common names, the inadequacy of common names, and the binomial system as applied to proper names. The basis of classification offers opportunity for making students realize both the practical importance of adequate classification and the practical difficulties of establishing a satisfactory classification. For the purpose of getting hold of principles of classification, experience with postage stamps, books, pottery, and textiles may be quite as illuminating as experience with flowers or fishes or frogs. The only advantage of experience with the sorting of organisms lies in the suggestion of a natural order.

Where opportunity and interest are present, encourage students to attempt the identification of species with the aid of some manual.

As a means of facilitating thought about relationships, tables and "trees" similar to those in the text should be constantly before the eyes of the students. It is therefore desirable to have large charts or wall paintings of these fixed points wherever feasible. It is especially recommended that a large portion of the bare wall, above the blackboards, be devoted to outline "trees" with the names of the phyla and chief subdivisions, accompanied by outline sketches of illustrative forms from the more familiar species. As reference is made to one or another species of plant or animal during the course of the year's study, the teacher may lightly indicate the place of the species in the system as a whole, — orient without elaborating. More can be achieved by this constant repetition through a long period than by devoting the same amount of time to intensive study of charts and tables and manuals. Encourage students to transcribe portions of the tables for special groups, and to prepare larger diagrams for the classroom wall.

Apart from the general features of the classification schemes, the significant point of the discussion is the basis for distinguishing between higher and lower plants and animals. This is to be considered with constant regard for the fact that the lowest are quite as capable of *living* as the highest, while it is legitimate to bring out the important differentia of human life as *the* highest.

References. Manuals for the classification and identification of common flowering plants (including trees), ferns, mosses, common fungi, birds, insects, fishes, reptiles, batrachians, and mammals. Natural-history books.

LXXXVIII. MAN AND HIS RELATIVES

This study may serve as a summary of the common facts about animal organization and functions.

Use pictures, plaster casts, relics of primitive man; have museum studies. Have special reports on traces of aborigines in the neighborhood and on current topics related to man's ancestry.

The argument is essentially a successive differentiation of man from the invertebrates to the primates.

The common argument that the similarity between man and the lower primates appeals even to the least intelligent must not be pushed too far. The resemblance that appeals may be entirely superficial. Young children are quite satisfied to treat dogs and cats exactly as they treat human beings; that is, there is enough similarity to appeal to their intelligence. Savages attribute to other animals and even to inanimate forces their own type of purpose and thought. This obvious similarity may thus prove too much. It is necessary to consider similarities that indicate relationship in the biological sense. That is, we must separate what men and monkeys have in common with other animals from what they have together that is different from other animals; and then we must consider the points of difference between man and other primates, with a view to determining whether these differences are so radical in kind or degree as to preclude evolutionary relationship.

References. CLODD, The Childhood of the World, chaps. i–iv; DARWIN, Descent of Man, chaps. i, vi, vii; DUCKWORTH, Morphology and Anthropology, chaps. ii, vii, viii; HOLMES, Animal Biology, chap. xxii; HOLMES, Evolution of Animal Intelligence, chaps. xi–xiii; HUXLEY, Man's Place in Nature; JORDAN and KELLOGG, Evolution and Animal Life, chap. xxi; OSBORN, Man in the Old Stone Age; SPURRELL, Modern Man and his Forerunners, chaps. ii, iii; TYLOR, Anthropology, chaps. i–iii; WATSON, Behavior, chap. x.

LXXXIX. MAN'S BRAIN

Since the significant part of this study has to do with the *results* of brain work rather than with the structure and workings of the brain, the latter need not be emphasized unless there is special interest in the subject among the students. Use a model of the human brain, and of such other vertebrate brains as are to be had. A calf's brain from the butcher may be dissected for gross features.

Have special readings and reports on museum studies on the activities of primitive man, comparing them particularly with the corresponding activities of other animals.

The question to emphasize is, How does man, despite his structural shortcomings, manage to adjust himself to the inimical aspects of his environment, and how does he manage to supply his needs?

References. For the pupils: DARWIN, Descent of Man, chaps. iii–v; TYLOR, Anthropology, chaps. iv–xii. For the teacher: DONALDSON, The Growth of the Brain; LANKESTER, Nature's Insurgent Son; LOEB, Comparative Physiology of the Brain.

XC. MAN'S CONQUEST OF NATURE — XCI. SCIENCE AND CIVILIZATION

Man the organic mechanism is gradually replaced by man the designer and creator. The isolated animal supplying his own wants and meeting his personal difficulties is gradually replaced by a member of society. Now he hunts in groups and solves his other problems through interchange of service and experience, and through coöperative effort in many directions. The study of biology merges into the study of psychology and sociology. The study of man is no longer physiology, but anthropology, ethnology, politics, and economics.

The text should be supplemented by assigned readings along divergent lines, depending upon the interests of the students and upon the available material. Local relics of ancient times and local institutions that embody the highest achievements in the way of organized research are equally significant in the final synthesis. The visit to the museum of natural history may well be supplemented by a visit to the historical museum or to the art museum; for here, in the consideration of man's achievements, the study of nature passes into the study of history and art.

The study of recent statistical material indicating measurable progress in man's conquest of his environment, and the comparison of local conditions in various respects with the general conditions, will help to fix the interest and perhaps to widen the outlook. The emphasis should be finally upon the value of civilization in terms of life more abundant, to which all science must contribute.

References. CLODD, The Childhood of the World; CONN, Social Heredity and Social Evolution; HODGE and DAWSON, Civic Biology, chaps. xxxi–xxxii; KELLICOTT, Social Direction of Human Evolution; LANKESTER, Nature's Insurgent Son; SPURRELL, Modern Man, chaps. iv–vii; TYLOR, Anthropology, chaps. xiii–xvi. Current reports of progress in applied knowledge.